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DEVELOPMENT PLAN FOR MILITARY WATER QUALITY CRITERIA FOR SPECIF--ETC(U)

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DEVELOPMENT PLAN
FOR MILITARY WATER QUALITY CRITERIA FOR SPECIFIC WASTEWATER REUSE APPLICATIONS

FINAL REPORT
June, 1979

by
Russell L. Culp

Project Officer: James C. Eaton, Jr.
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and

U.S. ARMY MOBILITY EQUIPMENT R&D COMMAND
Fort Belvoir, Virginia

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This report presents plans which are to be used in a subsequent effort to develop detailed quality criteria for waters derived from wastewaters. The U.S. armed forces are contemplating the reuse of renovated wastewaters for specific military purposes including short-term (1 to 7 days) non-potable reuse in the field and long-term (more than 7 days) non-potable and potable reuse at fixed installations.

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The study proposes the use of conventional numerical standards or maximum contaminant limits wherever possible. However, there may be instances where it is advantageous to specify a certain treatment process to remove a given contaminant or group of contaminants. In these cases, consideration will be given to use of unconventional standards or treatment standards.

The primary purpose of this study is to point the way to development of the required reuse criteria as rapidly and efficiently as possible.

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PURPOSE OF STUDY

This report presents plans which are to be used in a subsequent effort to develop detailed quality criteria for waters derived from wastewaters. The U.S. armed forces are contemplating the reuse of renovated wastewaters for specific military purposes including short-term (1 to 7 days) non-potable reuse in the field and long-term (more than 7 days) non-potable and potable reuse at fixed installations.

The Army and Navy have a high priority to develop non-potable criteria by 1980 and potable criteria by 1983. Because of the different time schedules and great differences in the possible health effects between non-potable and potable reuse, two separate development plans have been prepared. Non-potable reuse is discussed in Part A and potable reuse in Part B of this report.

The study proposes the use of conventional numerical standards or maximum contaminant limits wherever possible. However, there may be instances where it is advantageous to specify a certain treatment process to remove a given contaminant or group of contaminants. In these cases, consideration will be given to use of unconventional standards or treatment standards. This approach has recently been used by the EPA with regard to trace organics, where granular activated carbon adsorption is specified for removal of a wide variety of organic contaminants from drinking water sources.

The primary purpose of this study is to point the way to development of the required reuse criteria as rapidly and efficiently as possible. Research or demonstration work should be done only as absolutely necessary to develop or gain acceptance of the quality criteria. Most, but perhaps not all, of the background data needed for production of criteria are already at hand. However, the exact nature and scope of any needed research and demonstration work cannot be decided precisely until the actual preparation of standards is underway. It is anticipated that any necessary new investigative work to be done probably will be in those areas where treatment standards (rather than numerical limits) are to be used, but this remains to be seen. In estimating the level of effort which may be involved in the development of quality criteria for non-potable and potable reuse, an allowance has been made for some new research and demonstration work which can be included or deleted, preferably as the persons preparing the criteria reach a decision during the course of their work.

PART A
PLAN FOR DEVELOPMENT OF MILITARY NON-POTABLE REUSE CRITERIA

As discussed in the body of this report, it is anticipated that a total of nine sets of criteria for non-potable reuse must be developed, three for military field use, and six for fixed installations. These are tabulated below:

NON-POTABLE REUSE CRITERIA FOR MILITARY FIELD USE

Criteria Set No.	Reuse Criteria For Indicated Use	Wastewater Source	Type of Human Contact
1	Shower & washroom	Shower & washroom	Direct and limited accidental ingestion
2	Laundry	Laundry	Indirect external
3	Vehicle & aircraft washing, engineering construction, dust control	Miscellaneous	Incidental, mainly with the hands

NON-POTABLE REUSE CRITERIA FOR FIXED MILITARY INSTALLATIONS

Criteria Set No.	Reuse Criteria For Indicated Use	Wastewater Source	Type of Human Contact
Criteria set numbers 1, 2, and 3 are the same as for field use, except that the criteria for fixed installations may be more restrictive due to greater length of exposure.			
4	Swimming	Miscellaneous	Direct and limited accidental ingestion
5	Irrigation	Miscellaneous	Incidental
6	Industrial (cooling towers, boilers, scrubbers, washracks, paint shops, machine shops)	Miscellaneous	Incidental

In developing criteria for water to be reused in showers, laundries, and for swimming pools, the results of past and current studies of eye and skin irritants must be considered in addition to existing standards for swimming pool water of the American Public Health Association and the Conference of State Sanitary Engineers.

For irrigation waters the existing regulations of California or other states may be adaptable to military needs.

At fixed installations, the chemical quality of cooling tower, boiler and scrubber waters are the subject of engineering design and performance criteria, and do not involve health effects to any large extent.

In the field, hospital operating room, laboratory, x-ray, and kitchen, wastewaters are not considered suitable for reuse. In permanent bases, wastewaters from plating and photographic laboratories are not considered suitable for reuse.

The persons developing reuse criteria should evaluate toxicological hazards,

determine acceptable risks, and establish contaminant levels accordingly. They must keep in mind the interrelations between source, type of reuse, treatment, testing, and monitoring. The reliability of treatment processes, equipment, and operations is a very important factor. It is doubtful that any new research or demonstration is required; rather, the criteria should carefully prescribe the degree of reliability to be provided. The degree of reliability required will have a significant impact on cost.

Recommended Procedure

Non-potable reuse criteria could be developed either in-house by the military or by a contractor employed by the military. In either case, the first step would include: literature review, evaluation of treatment methods, making of risk assessments, selection of testing and monitoring techniques, and the preliminary drafting of non-potable criteria. After not more than 5 months of work along these initial lines, it should be possible to identify any essential areas of new research or demonstration which may be essential to completion of the work.

It is estimated that the development of criteria for non-potable field use might require one to two man-years of effort. Criteria development for non-potable reuse at fixed installations would require one additional man-year. The total level of effort for the nine sets of non-potable criteria development might amount to two to three man-years, exclusive of any related new research or development projects.

The estimated level of effort to establish the suitability of any treatment requirements for non-potable reuse is one to two man-years of professional time plus $50,000.00 to $100,000.00 for equipment and supplies. Further, it is estimated that an equal level of effort both in manpower and materials could be expended to advantage toward developing new rapid field test procedures and apparatus. The range of total effort which might be required would be in the neighborhood of two man-years as a minimum to seven man-years plus $200,000 as a maximum.

After the decision is made regarding the need for research or demonstration projects, it is estimated that the draft non-potable criteria could be completed in another eleven months. The drafting of standards would proceed concurrently with the research and demonstration projects. Military staff would then review the interim criteria within a two-month period. Then the criteria would be submitted to the National Academy of Sciences for their review and concurrence in the procedures and protocol followed in development of the criteria, and to the Surgeons General for their approval and adoption. These final review procedures are estimated to take three months. This time schedule provides for adoption of non-potable reuse criteria by the end of the 1980 fiscal years. If no new research or demonstration projects are needed, the work could easily be completed by the middle of the 1980 fiscal year.

PART B
PLAN FOR DEVELOPMENT OF MILITARY POTABLE REUSE CRITERIA

One additional set of criteria would be needed for potable reuse of

renovated wastewater by the military at fixed installations. Initially, it is expected that these criteria might be much more restrictive than the present EPA standards for drinking water from fresh water sources. Even where, to avoid the need for demineralization, it is proposed to limit the amount of recycled wastewater to about one-third of the total supply, an amount that may be present at times in existing public water supply sources, it is almost certain that the water quality criteria for intentional reuse will be more restrictive than the present drinking water standards.

The chief concerns with potable reuse of renovated wastewater lie in the areas of bacteriology, virology, and toxicology, and in the reliability of treatment plant operation.

The approval of non-potable criteria probably can be limited to that required within the military with review of procedures by NAS.

Potable criteria are going to be subjected to much closer scrutiny by agencies with both official and unofficial responsibilities.

The key to acceptance of wastewater reuse for potable purposes is the declaration by a recognized and respected scientific authority that reuse is safe from a health standpoint.

It is apparent that the civilian sector is not going to develop reuse criteria in time to meet military needs. Also military requirements and conditions may not be identical to civilian needs and situations.

Recommended Procedure

It is recommended that the potable reuse criteria be developed under military contract by a special task group supported by clerical staff. The Task Group could consist of a bacteriologist-virologist, a toxicologist, and a sanitary engineer with experience in water quality criteria development. They should be chosen from the top experts in the country. If the Task Group is to function properly and efficiently, experience has shown that they must be given staff support for editing, typing, and related services. This could be furnished by a consulting firm employed by the military.

The Task Group would be responsible for development of potable reuse criteria by the end of fiscal year 1983.

Possible alternatives to the Task Group would be preparation of the criteria by NAS or a consulting firm.

As with non-potable reuse, there is a question as to whether or not new research or demonstration projects will be essential to criteria development. In this case, the decision regarding these projects probably should be made by the military at about the same time that the type of contractor to develop potable criteria is selected, so that the health effects research

needed and the drafting of criteria can proceed simultaneously.

This report suggests that health effects research in certain areas of virology, bacteriology, trace organics removal, and toxicity may be of assistance in developing or securing acceptance of criteria for potable reuse.

There are several tasks to be included in the contract for potable criteria development. These tasks would include a literature review of existing drinking water standards for water derived from conventional sources and related background studies, reports of health effects research, operating reports from existing wastewater reuse projects, latest treatment methods, new analytical and monitoring methods, objections to wastewater reuse, and related on-going research. The criteria development contractor would also evaluate treatment methods and specify fail-safe techniques to be employed in renovating wastewater. Finally, the criteria development contractor would draft interim potable criteria which would include conventional numerical standards plus specified treatment techniques where advantageous. The contractor would also recommend operational and monitoring procedures with a view toward plant reliability and fail-safe operation.

During the time that criteria are under development, there would be in progress health effects research by the military, the EPA, universities, and other agencies. The criteria contractor should keep abreast of this work and incorporate any appropriate new information or techniques in his work.

Military and NAS review of the contractor's work should be made at quarterly intervals. Upon completion of the criteria, the NAS should be asked to review the protocol and procedures which were followed in their preparation. The criteria should be submitted to the Surgeons General for approval.

If the potable criteria are developed by a three man task group, the level of effort required is estimated at 36 man-months of professional labor, 2 man-months of secretarial labor, and $24,000 in expenses.

It is thought that a consulting firm might accomplish this same task at slightly lower cost because of savings in time due to fewer persons being involved in the project and in travel to meetings, and elimination of some duplication of effort and time for communication among workers. Under this alternate, the level of effort is estimated to be 30 man-months of professional time, 1 1/2 man-months of secretarial time, and $5,000 in expenses.

In addition, as much as eight man-years might be invested in health effects research and demonstration projects, plus $50,000 to $100,000 for a pilot or demonstration plant.

If work on the development of potable reuse criteria is started in December of 1978, and completed as scheduled, potable criteria would be available in September, 1983.

INTRODUCTION

The objective of this report is to prepare and present plans for the subsequent development by others of military water quality criteria for human reuse of renovated wastewater for specific purposes by the U.S. armed services. It is not the purpose of this report to actually develop water reuse criteria. Reuse for both potable and non-potable purposes are considered. These two types of reuse differ so greatly in so many respects that two separate plans have been prepared, one for development of non-potable reuse criteria and another for development of potable reuse criteria. Part A of this report discusses non-potable reuse criteria for both field operations and fixed installations. Part B discusses potable reuse at fixed installations. Potable reuse by the military in the field is not proposed at the present time. For non-potable reuse, several sets of quality criteria will be needed to suit different wastewater sources and different water uses. The emphasis for the immediate future is on non-potable field reuse.

There is a high priority by the Army and the Navy for development of non-potable criteria by 1980, and for potable reuse criteria by 1983. This is illustrated by Figure 1. Criteria are needed to provide a basis for design of treatment units, for specification of process control and monitoring instrumentation, and acceptance of the final hardware. The urgency arises from the need to obtain the acceptance of approving authorities within military hardware development schedules.

Under field training conditions and at fixed military installations the acceptability of risks involved in water reuse is similar to that for civilian communities. Only under combat conditions does the mission of the military forces dictate a different hierarchy of risks. Criteria must recognize the differences between one-time emergency (short-term) and long-term water use. Definitions of short-term and long-term use are given in the American-British-Canadian-Australian Quadripartite Standardization Agreement-245 as adopted in 1975. This agreement deals with minimum requirements for water potability. It defines short-term field water consumption as a period of one to seven days, and long-term consumption as a period in excess of seven days. The need for criteria for an intermediate length of exposure has been expressed by military agencies having responsibility for water supply and distribution as well as representatives of the commands who would be the ultimate users.

The development plans suggest the use of conventional numerical standards and non-conventional (treatment standards) criteria. The development plans also point out the possible usefulness of interim guidelines to serve until permanent standards or criteria can be provided. In developing the criteria, existing standards, criteria, treatment requirements, rationales, protocols, and data should be utilized as much as possible in order to minimize new research requirements and thus to minimize the time and dollar requirements of the project.

Figure 1

CRITERIA DEVELOPMENT

Fiscal Year 1978	Fiscal Year 1980	Fiscal Year 1983
DEVELOPMENT PLANS	NON-POTABLE CRITERIA*	POTABLE CRITERIA
	a. For short term use (1 to 7 days) under combat and emergency conditions. b. For long-term use (more than 7 days) at fixed installations.	a. For long-term use at fixed installations.

*For each category of non-potable reuse there will be several sets of criteria developed for different sources of wastewater and for various uses of the renovated wastewater.

PART A

PLAN FOR DEVELOPMENT OF MILITARY WATER QUALITY FOR NON-POTABLE REUSE

THE TASK

It is fortunate that the highest priority needs of the military services are for short-term, non-potable reuse in field operations. As compared to the job of development of criteria for long-term potable reuse of wastewater, the task of establishing non-potable criteria should be much easier and less time-consuming. There are several reasons why this is so. In every case of non-potable reuse, the health risk would seem to be less than for potable reuse. Further, the military environment in which the non-potable water quality criteria are to be applied is unique in many respects. The wastewater sources to be utilized in the field may be separated so as not to include human wastes. This separation probably would be made in most cases, but perhaps not in all cases. The length of exposure and the composition of the population exposed may be limited and controlled. The make-up of the wastewaters is better defined than is the case with municipal systems. It is also possible to select the most favorable sources of wastewaters to be treated for reuse. One important factor is that approval for non-potable reuse in the field in combat and under short-term emergency conditions could undoubtedly be limited to approval by the military.

The principal non-potable field uses of renovated wastewater is the reuse of laundry water for laundry and the reuse of shower and washroom wastes for the same purposes. Further, the military is already using, under certain field conditions, raw untreated water in laundries and washrooms, so that a precedent is already established for use of a second water supply of sub-potable quality for these purposes.

Laundry water recycling as practiced in many American cities is a comparable non-potable reuse to that already described for the military.

Consideration should be given to the costs and risks of non-potable reuse as compared to the benefits derived. The strategic benefits of reuse are the freeing of trucks and other vehicles to transport ammunition, gasoline, and other military supplies, rather than to use them for hauling water. The sources of wastewater and the uses of renovated water for non-potable purposes must be chosen so that a net positive benefit is produced. If this cannot be done in certain situations, then these reuse applications will not be developed.

It bears repetition here that there may be risks which are acceptable in combat that are unacceptable either to the population at large or during military training.

TYPES OF NON-POTABLE REUSE CRITERIA

At a meeting held in Fort Detrick in 1978, representatives of the Army, Navy, and the Air Force developed water reuse priorities based on a listing of wastewater sources and possible uses for renovated wastewater which they prepared. The findings of this group are presented in Table 1.

Please note that all 22 uses of water tabulated are applicable to fixed installations, but that only 12 (items number 1 through 10, plus 18 and 21) are applicable to field troops. Also note that metal plating shops and photographic laboratories are not considered to be suitable sources of wastewater for reclamation because of the high contaminant levels, nor to be potential users of renovated water because of very high quality requirements. Also kitchens, bakeries, and graves registrations are questionable sources and points of use with regard to wastewater and renovated water. Further, reuse for human consumption is not presently propósed for the field military. Other uses of water which are not considered good sources of wastewater for renovation are: engineering construction, vehicles, irrigation, paint shops, and dust control, for obvious reasons.

Categories of Non-Potable Reuse

Non-potable reuse of water involves three degrees of human contact, namely, direct, indirect, and incidental. These types of exposure are experienced in both the field and in fixed installations. At fixed installations there is a potential fourth type of contact, that of human ingestion. This is illustrated by Table 2. As previously mentioned, a distinction must be made in water quality criteria between short-term field use and long-term use at fixed installations in view of any differences in health risks which can be attributed to duration of exposure. Criteria for non-potable reuse should include specified tests for water quality control.

The reuse of laundry, shower, and washroom wastes for these same non-potable purposes raises the question of possible eye or skin irritation. Reuse for swimming and showers involves accidental or limited ingestion. Vehicle and aircraft washing and other industrial uses provide only incidental human contact, mainly with the hands, but inhalation of aerosols from industrial operations (painting) should be addressed.

APPROACH TO ESTABLISHMENT OF WATER QUALITY CRITERIA FOR NON-POTABLE REUSE

The establishment of water quality criteria for reuse of renovated wastewater for military non-potable reuses should be a relatively simple undertaking which can be accomplished without difficulty by 1980 or before, if resources are provided for this task. The criteria should include those for quality and sources of water to be reclaimed as well as specified tests for quality control. The tasks could be done in-house by military staff or by a consultant employed by the military.

Referring back to Table 1, it shows military uses of water in the field

TABLE 1
MILITARY WATER USES/SOURCES

Description Use/Source	Reuse Use	Reuse Source	Field Army	Rqmts. For 100,000 Men In Arid Areas, 1,000 gpd	Priority	Comments
1. Laundry	X	X	X	17	1	Reuse/recycle in place, makeup to last rinse.
2. Shower/washroom	X	X	X	17	1	Reuse/recycle in place.
3. Kitchen & bakeries	?	?	X	22	4	Possible reuse/conservation w/o treatment.
4. Hospital	?	?	X	9	4	Most uses common to other field army.
5. Indiv. consumption	0	0	X	64	5	Potable reuse not considered in field.
6. Graves Registration	?	?	X	2	Unknown	More information needed.
7. CBR Decon.	X	X	X	Unknown	Unknown	May be high priority, but not in this study.
8. Engr. Construction	X	0	X	450	3	Transport of non-potable water in field created hazard of confusion with potable.
9. Aircraft	X	X	X	5	3	
10. Vehicles	X	0	X	1	3	
11. Irrigation	X	0	0		2	Highest user for USN-fixed bases, criteria developed by civilian sector may apply.
12. Cooling towers	X	X	0		3	Industrial uses highest USAF priority.
13. Boilers	X	X	0		3	" " " " "
14. Scrubbers	X	X	0		3	" " " " "
15. Washracks	X	X	0		3	" " " " "
16. Painting	X	0	0		3	" " " " "
17. Machine Shop	X	X	0		3	" " " " "
18. Turbine washing	X	X	X		3	" " " " "
19. Plating	0	0	0			Demand high quality water, produce high contaminant level, treat for discharge.
20. Photo lab	0	0	0			
21. Dust control	X	0	X			
22. Swimming	X	X	0		1	Navy Non-CONUS (some sea water installation)

Legend: X = Yes ? = Questionable
0 = No

TABLE 2

TYPES OF WATER REUSE AND DEGREES OF HUMAN EXPOSURE

	LOCATION AND TYPES OF REUSE	
HUMAN EXPOSURE	FIELD FORCES	FIXED INSTALLATIONS
Ingestion	Not proposed	Drinking and cooking (See Part B of this report.)
Direct Contact Limited Ingestion	Showers	Showers and swimming
Indirect Contact	Laundries	Laundries
Incidental Contact	Vehicle and aircraft washing, engineering construction, and dust control	Irrigation, vehicle and aircraft washing, and other industrial uses

and at fixed bases, identifies potential reuse sources, gives water quantities required for certain field conditions, and gives priorities for reuse. Referring back to Table 2, it indicates the locations and general types of reuse, both for field forces (one-time, short-term emergency use) and for fixed installations (long-term use). As mentioned several times previously, several sets of criteria must be developed for different wastewater sources and different reuse purposes, the principal divisions being between field military and fixed installations.

Water Quality Criteria for Non-Potable Reuse for Field Forces

As already seen, laundry, shower, and washroom wastewaters are the best prospects for renovation and reuse by field troops. Table 3 shows the concentration of chemicals and materials for synthetic MUST (Medical Unit, Self-contained, Transportable) Army Field Hospital laundry wastewater and shower wastewater. Table 3 does not show the composition of those individual field wastewater streams which are not considered candidate sources for reuse including: hospital operating room, laboratory, x-ray, and kitchen.

Criteria should be developed for renovation of laundry wastewater in place with recycle to the laundry from makeup to last rinse.

Criteria should also be developed for treatment of shower and washroom greywaters in place with recycle and reuse for these same purposes.

Renovated wastewater for vehicle and aircraft washing, engineering construction, and dust control can be produced from a wide variety of field sources, and it may be possible to develop a third set of criteria for these uses for any of the individual sources or combinations of different wastewaters making up a source.

During the development of non-potable water quality criteria for field reuse, the relationships between source and criteria, use and criteria, and treatment and criteria must be constantly kept in mind.

The persons responsible for the development of criteria must attempt: (1) to evaluate the extent of any toxicological hazards which may be involved; (2) determine acceptable risks, if any; and (3) establish maximum contaminant levels accordingly. Specific treatment systems and water quality tests may be included as a part of the criteria.

In the general case of non-potable reuse of renovated wastewater, and especially for short-term, one-time, field exposure in combat or other emergencies, it is possible that all of the information may already be at hand, both for development of the necessary criteria, and processing equipment. However, this cannot be determined with certainty until the tasks of criteria development and equipment development are complete. It may be that the reuse criteria may contain treatment requirements as well as numerical standards. If this is the case, then it may be necessary to do some research or demonstration work to establish the suitability and reliability of the treatment processes and equipment selected

**TABLE 3

CONCENTRATIONS OF CHEMICALS AND MATERIALS FOR SYNTHETIC MUST HOSPITAL SHOWER AND LAUNDRY WASTES

MUST Waste	Constituent	Concentration
1. Shower	Hair oil	150 mg/l
	Shower/lavatory cleaner	100 mg/l
	Sodium chloride	83 mg/l
	Soap	69 mg/l
	Hair gel	37 mg/l
	*Toothpaste	37 mg/l
	Talc	20 mg/l
	Soil (kaolinite)	19 mg/l
	Hair	10 mg/l
	Hair shampoo	5 mg/l
	*Phisohex soap	3 mg/l
	*Mouthwash	2 mg/l
	DEET (insect repellent)	1 mg/l
	Deodorant	1 mg/l
	Hair coloring	1 mg/l
	Hair dye	1 mg/l
	Urea	1 mg/l
2. Laundry Type I	Detergent Type I (FSN 7930-634-3935)	650 mg/l
	Alkalinity	500 mg/l
	Oil and grease (vegetable oil)	200 mg/l
	Kaolinite clay	150 mg/l
	Sour (Downey fabric softener)	116 mg/l
	Urea	20 mg/l
	DEET	19 mg/l
	*Blood	874 µl/l
3. Laundry Type II	Detergent Type II (FSN 7930-664-0337)	518 mg/l
	Alkalinity	500 mg/l
	Sour (Downey fabric softener)	116 mg/l
	Kaolinte clay	100 mg/l
	Oil & grease (vegetable oil)	100 mg/l

*These items are peculiar to field hospital wastes, the subject of the Gollan study from which this table was taken, and are not likely constituents of normal field hospital wastes.

**Table 3 is taken from Appendix A, "Evaluation of Membrane Separation Processes, Carbon Adsorption, and Ozonation for Treatment of MUST Hospital Water", by Gollan, A.Z., et al, USAMBRDL, August, 1976.

for meeting the treatment requirements. It may also be advantageous to attempt to develop special testing and monitoring equipment for field use. In selecting or developing equipment for wastewater renovation, attention should be given to the possibility that some processes or equipment may be made fail-safe, that is, if the unit fails, no water is produced. It is estimated that the development of the criteria for non-potable field use might require one to two man-years of effort.

The estimated level of effort to establish the suitability of any treatment requirements for non-potable reuse is one to two man-years of professional time plus $50,000.00 to $100,000.00 for equipment and supplies. Further, it is estimated that an equal level of effort both in manpower and materials could be expended to advantage toward developing new rapid field test procedures and apparatus.

In the matter of approval of the non-potable criteria for field use, it appears that this rests almost entirely within the military services where approval of the Surgeons General would be sought. Civilian agencies will have little or no interest in this subject (in contrast to their probable strong interest in criteria for potable reuse).

It would be very worthwhile to have the National Academy of Sciences review the procedures and protocols followed in the development of the non-potable reuse criteria for use under combat or other short-term emergency conditions and to have their concurrence in the methods used in arriving at the criteria. But it appears proper and sufficient, in this case, that final approval of the criteria rest solely with the military.

The suggested approach to development of non-potable reuse water quality criteria is illustrated by Figures 2 and 3 which appear at the end of this Part A.

Water Quality Criteria for Non-Potable Reuse for Fixed Installations and Military Field Training

As just seen, it is probable that at least three sets of criteria will be necessary for possible short-term use in combat or other emergencies. These are:

1. Criteria for shower and washroom water to be produced from shower and washroom wastewaters. This type of reuse involves direct human contact and limited, accidental ingestion.

2. Criteria for laundry water to be renovated and recycled from laundry wastewater. This type of reuse involves only indirect external human contact, mainly with clothing, bedding, washcloths, and towels.

3. Criteria for vehicle and aircraft washing, engineering construction, and dust control. This type of reuse involves only

incidental human contact, mainly with the hands.

For long-term exposure in military training or at fixed military installations, a part or all of these three sets of criteria may be applicable. However, it is much more likely that another corresponding group of three sets of criteria will be required which take into account the longer exposure time. These criteria are likely to be more restrictive.

In addition, it will be necessary to develop sets of criteria for:

4. Swimming, a type of use involving direct human contact and limited, accidental, ingestion.

5. Irrigation, a type of use involving incidental human contact.

6. Cooling towers, boilers, scrubbers, washracks, painting shops, machine shops, and other industrial type uses involving only incidental human contact. These industrial uses may have common health considerations but different chemical constituent requirements depending upon industrial process needs.

The development of water quality criteria for swimming should be a relatively simple and easy matter. Most, if not all, state health regulatory agencies have already established standards for swimming pools and bathing beaches. It is possible that the most appropriate state standards could be adopted as is by the military. If not, the most that might be required would be minor modifications.

The American Public Health Association and the Conference of State Sanitary Engineers have published (1964) a manual entitled, "Design, Equipment, and Operation of Swimming Pools and Other Public Bathing Places". This manual includes information on the desired chemical, physical, and bacteriological quality of public swimming pool water, and the bacteriological quality of other outdoor bathing places (ocean beaches, lakes, etc.). The chemical and physical parameters are limited to clearness (turbidity), acidity-alkalinity, temperatures, and excess chlorine.

There will be special considerations in standards for swimming pool water derived from wastewater. One example is synthetic detergents which would have to be reduced to a level which would not cause frothing (say, less than 0.5 mg/l). There would be other similar considerations involved, because of the water source, in adopting or formulating swimming pool criteria.

Human exposure to water in showers and washrooms is similar to that encountered in swimming; and it is possible that criteria for swimming pool water could be adopted or adapted for shower and washroom waters.

Past and current studies of eye and skin irritants in reclaimed wastewater should provide additional criteria for shower water, swimming pool water, and possibly for laundry water.

At fixed installations, ordinarily the principal use of renovated wastewater undoubtedly will be for irrigation. For irrigation waters, existing criteria already developed and used by the civilian sector may apply.

There are a number of sets of existing regulations for various types of irrigation waters including those for California, Israel, South Africa, and the Federal Republic of Germany, as shown in Table 4. These can be used or adapted to suit conditions on military posts.

At fixed installations, the chemical quality of cooling tower, boiler and scrubber waters are the subject of engineering design and performance criteria, and do not involve health effects to any large extent.

In permanent bases, water reused for plating and photo lab waters must be very high and uniform in chemical quality; and wastewaters from these sources are poor candidates for reuse because of heavy contamination, but treatment for recycle of both water and chemicals may prove economical in these processes.

Hospital operating room wastes are of poor quality and have a low priority for reuse, but constitute a waste disposal problem for field hospitals.

For fixed military installations it appears that at least six sets of non-potable water quality criteria would have to be developed, including those for: (1) shower and washroom water, (2) laundry water, (3) vehicle and aircraft washing, engineering construction, and dust control, (4) swimming, (5) irrigation, and (6) cooling towers, boiler scrubbers, washracks, painting shops, machine shops, and miscellaneous industrial purposes.

As with the non-potable criteria for field use, it appears that these could be developed in-house by military personnel or by a contractor employed by the military.

The estimated effort to develop the non-potable criteria for fixed installations is about one man-year in addition to that for the field non-potable criteria. It appears unlikely that further testing or demonstration effort beyond that described earlier for field non-potable criteria would be required for fixed installations; the testing could be combined for both purposes.

Once preliminary non-potable reuse water quality criteria are developed for fixed installation, they should be submitted to the Surgeons General for approval.

As before, the National Academy of Sciences should be asked to review the procedures and protocols involved in producing the standards to secure their concurrence in the methods employed.

It is doubtful that any civilian agencies or authorities are going to be particularly interested or helpful in the promulgation of the non-potable reuse water quality standards.

TABLE 4

EXISTING STANDARDS GOVERNING THE USE OF RENOVATED WATER IN AGRICULTURE

	California*	Israel	South Africa	Federal Republic of Germany
Orchards and vineyards	Primary effluent; no spray irrigation; no use of dropped fruit.	Secondary effluent.	Tertiary effluent heavily chlorinated where possible. No spray irrigation.	No spray irrigation in the vicinity.
Fodder, fibre crops, & seed crops	Primary effluent; surface or spray irrigation.	Secondary effluent, but irrigation of seed crops for producing edible vegetables not permitted.	Tertiary effluent.	Pretreatment with screening and settling tanks. For spray irrigation, biological treatment and chlorination.
Crops for human consumption that will be processed to kill pathogens	For surface irrigation, primary effluent. For spray irrigation, disinfected secondary effluent (no more than 23 coliform organisms per 100 ml).	Vegetables for human consumption not to be irrigated with renovated wastewater unless it has been properly disinfected (<1,000 coliform organisms per 100 ml in 80% of samples).	Tertiary effluent.	Irrigation up to 4 weeks before harvesting only.
Crops for human consumption in a raw state	For surface irrigation, no more than 2.2 coliform organisms per 100 ml. For spray irrigation, disinfected, filtered wastewater with turbidity of 10 units permitted providing it has been treated by coagulation.	Not to be irrigated with renovated wastewater unless they consist of fruits that are peeled before eating.		Potatoes and cereals - irrigation through flowering stage only.

*Wastewater Reclamation Criteria, California Administrative Code, Title 22, Div. 4, Environmental Health, California Department of Health, Sections 60301-60357.

Figures 2 and 3 are a Gantt Chart and a PERT chart, respectively, which present proposed steps and schedules that are suggested for development of non-potable criteria. See pages 14 and 15.

Water Quality Criteria Development for Non-Potable Reuse

As stated at the outset, the actual development of water quality criteria is beyond the scope of this report, which is intended to present a development plan which will be useful to others in the subsequent detailed promulgation of criteria. In the course of preparation of this report, several general considerations have arisen and have been discussed which may be useful later in the actual selection and identification of water quality parameters for reuse applications, and for that reason, are mentioned herein.

The potential health effects from the use of renovated wastewater may be divided into three broad categories: acute, sub-acute, and chronic. Acute health effects would occur almost solely from the intentional ingestion of water, rather than from external uses of non-potable water, and the criteria regarding possible acute effects of potable water are already well defined in the NIPDWR* of the U.S. EPA. Chronic effects from water reuse for non-potable purposes are not a factor in short-term (1 to 7 days) field military use. Chronic effects of non-potable reuse of renovated wastewater are a factor in long-term use at fixed military installations to about the same extent as in civilian communities. The sub-acute effects are probably those of most concern in short-term military field operations.

Table 5 presents a matrix of factors to be considered in the development of criteria for military non-potable reuse.

Figure 2 (Gantt Chart) and Figure 3 (PERT Chart) include provisions for new research and demonstration projects, in the event that they are needed for development of non-potable reuse criteria. It is entirely possible that the needed non-potable reuse criteria can be developed without further research and demonstration work. No specific needs along this line have been identified at this time. It is conceivable that if treatment techniques are specified as criteria, that it may be desirable or necessary to demonstrate their applicability or reliability by new demonstration projects. Also, if certain specified laboratory tests or monitoring requirements are not suitable for field military use, then there may be a need for new research in these areas. These are the two reasons for scheduling time in the development plans for research and demonstration projects. If future events and studies show that the criteria can be developed without new work in these areas, then the time schedules may be shortened.

*National Interim Primary Drinking Water Regulations

Figure 2. GANTT CHART FOR DEVELOPMENT OF QUALITY CRITERIA FOR NON-POTABLE WATER DERIVED FROM RENOVATED WASTEWATERS.

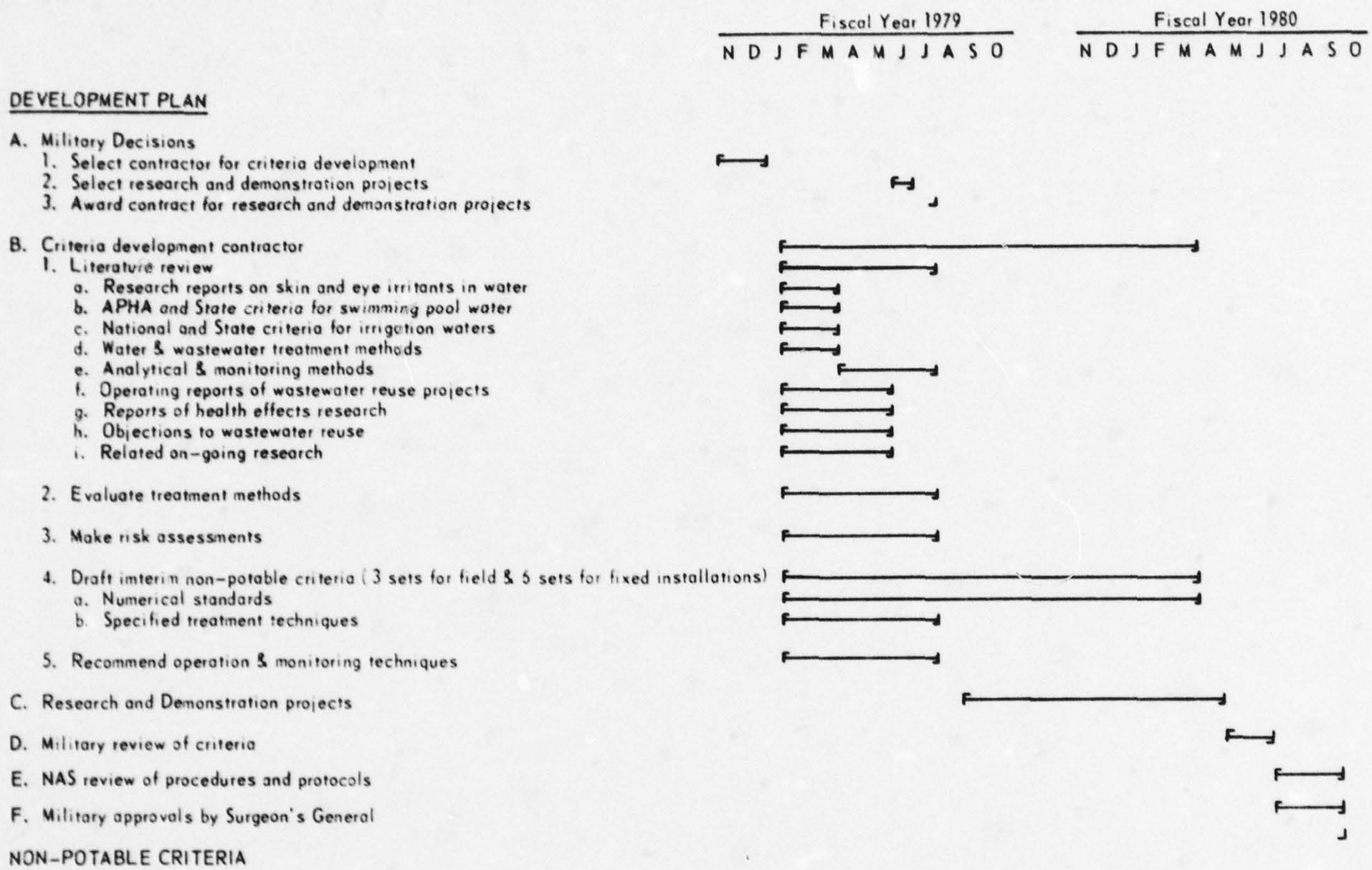


Figure 3. PERT CHART FOR DEVELOPMENT OF QUALITY CRITERIA FOR NON-POTABLE WATER DERIVED FROM RENOVATED WASTEWATER

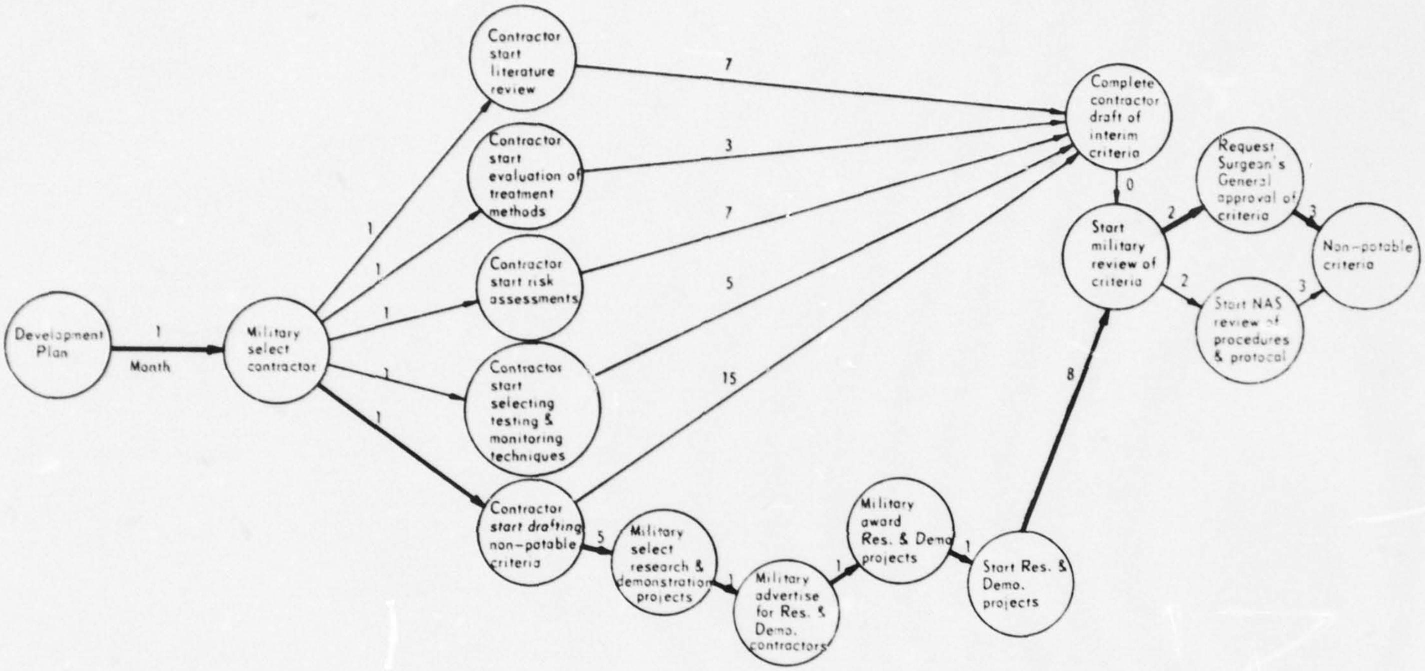


TABLE 5

WATER QUALITY CRITERIA DEVELOPMENT FOR NON-POTABLE REUSE

Reclaimed Water Use	Recycle/* Reuse	Criteria Parameters	Human Contact	Waste Constituents	Possible Effects	Available Criteria
Showers & Swimming Pools	Recycle	Chemical Biological	Dermatory Accidental Swallowing	Soap Disinfectant Insect repellants Scouring compounds Trace Human Waste	Sickness Aesthetic (Color, odor) Eye & Skin Irritation	APHA & State Stds.
Laundries	Recycle	Chemical Biological	Dermatory	Detergent Solvents Trace Human Waste	Skin Irritation	
Washracks & Industrial Uses	Reuse	Chemical Biological	Dermatory Respiration	Oil & Grease Detergents Paints Solvents Heavy Metals Phenol Chlorinated Hydrocarbons Cyanide	Sickness Eye & Skin Irritation	
Irrigation	Reuse	Chemical Biological	Dermatory Respiration	Chemical & biological components from domestic & industrial waste	Sickness Eye & Skin Irritation	National & State (e.g., California**) Stds.

*Recycle: Reclaimed water is originated from same facility operation (i.e., pipe-to-pipe connection).
Reuse: Reclaimed water is originated from same and other facility operation or solely from other facility operation.

**Wastewater Reclamation Criteria, California Administrative Code, Title 22, Division 4, Environmental Health, California Department of Health; Sections 60301-60357.

PART B

PLAN FOR DEVELOPMENT OF POTABLE REUSE WATER QUALITY CRITERIA

IMPORTANCE OF ESTABLISHING WATER QUALITY CRITERIA FOR REUSE

Potable Reuse

The military services have a need for water quality criteria for potable reuse of reclaimed wastewater in advanced/remote bases to support military operations in the field. The Navy has another reuse application, supplying water to remote semi-permanent bases outside of the United States where desalination is now required. There is also a need for criteria at fixed military installations where potable reuse is likely. Potable reuse at fixed military bases in the U.S. would be quite comparable to potable reuse in municipalities, for which there presently are no standards.

The main, long-term objective of this part of the project is aimed directly at the principal problem in implementation of potable reuse of wastewaters in civil life, which is the lack of quality criteria for potable use of water derived from wastewater sources. Many of the treatment, control, and monitoring technologies required for safe wastewater reuse are already at hand to meet any standards which might be set. However, the question as to whether all such technological needs are already met and questions concerning cost and practicability cannot be fully resolved until product requirements are precisely defined. The lack of quality criteria for renovated wastewater has seriously delayed implementation of reuse projects.

Ideally, standards could be formulated which would ensure the safety of water supplies regardless of source, and it seems reasonable to expect that this might eventually be done, but even separate, more restrictive standards for water derived from wastewater for potable and other types of reuse would be valuable.

Standards for drinking water have been available for many years. However, renovated wastewater meeting quality standards for drinking water are not accepted by health authorities because selection of the source of water is usually specified as a part of the standards.

In accordance with present standards, drinking water is to be obtained from the best source available without regard to economics. For water sources containing wastewater, this means that dilution, storage, sedimentation, and natural purification must take place. Time has always been considered a favorable element in reducing pollution, and groundwater recharge involving extended periods of underground storage can provide a considerable safety factor in wastewater renovation. Pipe-to-pipe renovation introduces additional risks.

The fact that health authorities do not now accept water meeting drinking quality standards if it is intentionally produced from wastewater, because of the "best source available" provision, makes it seem likely that a new separate standard for renovated wastewaters would be much more restrictive

than present drinking water standards. Despite the fact that there are risks in existing public water supplies, health authorities are reluctant to "compound the problem" by voluntarily adding new supplies from wastewater at risk.

In consideration of the similar problems which are involved in the treatment of some existing surface polluted water supply sources and wastewater, it is highly desirable to develop a single new set of standards for drinking water which are independent of source and subject to equal regulatory supervision, rather than to have a double standard. There is a bill (H.R. 11302) now under consideration in Congress which would require EPA to prepare supplemental standards or treatment technologies for renovated wastewaters within nine months of enactment.

There currently is considerable controversy between EPA (U.S. Environmental Protection Agency) and AWWA (American Water Works Association) over the proposed EPA regulations for Control of Organic Contaminants in Drinking Water. The proposed regulations contain two principal parts. Part I would establish a maximum contaminant level of 0.10 mg/l (100 ppb) for total trihalomethanes including chloroform. Part II prescribes a granular activated carbon treatment technique where synthetic organics are a problem. AWWA is questioning the need, advisability, and practicability of the proposed regulations. It is argued that the proposed regulations should not be adopted until there is more definite proof that trihalomethanes and synthetic organics are actually carcinogenic in humans at the concentrations found in drinking water.

This organics question is one of more immediate and urgent concern to health officials with respect to existing supplies than is the same question with respect to renovated wastewaters. Therefore, it appears that full consideration of criteria for organic concentrations in renovated wastewater may be delayed until the immediate problems of organics in existing drinking water supplies are resolved. Even then, it may or may not be possible to apply the organics standards for water supply quality and treatment requirements for drinking water from fresh water sources to renovated wastewaters.

CURRENT STATUS OF WATER QUALITY CRITERIA FOR POTABLE WATER

General

In 1952 the California State Water Quality Control Board published a bulletin on "Water Quality Criteria" by Jack E. McKee and Harold W. Wolf. The primary aim of this publication was to assemble, condense, and evaluate the readily available literature pertaining to water quality and its effects upon the beneficial uses of water. A second edition of this bulletin was published in 1963. This book contains good basic information on quality criteria for all major beneficial uses of water, and is an excellent reference for background material on various individual physical, chemical, and biological constituents.

Drinking Water Standards in the U.S. were first promulgated under the Treasury Department in 1914. These standards were modified and reissued

by the U.S. Public Health Service in 1925, 1942, 1946, and 1962. Presently, the physical, chemical, and bacterial quality of drinking water in the U.S. is judged by the National Interim Primary Drinking Water Regulations (NIPDWR) of the U.S. EPA. These regulations were issued in December, 1975 under the Safe Drinking Water Act of 1974 (PL 93-523). Currently there is under consideration, a proposed amendment to the NIPDWR for the "Control of Organic Chemical Contaminants in Drinking Water".

The Safe Drinking Water Act required the Administrator of the Environmental Protection Agency to arrange for a study that would serve as a scientific basis for revising the primary drinking water regulations that were promulgated under the Act. The Study was conducted by the Safe Drinking Water Committee of the National Research Council, National Academy of Sciences, under the chairmanship of Dr. Gerard A. Rohlich of the University of Texas at Austin.

A thorough study of the scientific literature was undertaken in order to assess the implications for human health of the constituents of drinking water in the United States. The NAS report, "Drinking Water and Health" was issued in 1977.

As mentioned previously, the Drinking Water Standards have always been predicated on a protected source of supply and use of the best available source. The accumulated water supply quality data and related health information which support the drinking water standards are based mainly upon records obtained from water systems having relatively unpolluted supply sources, but the records also include those of cities withdrawing water from the Ohio, Mississippi, Missouri, and other rivers containing various amounts of primary or secondary treated wastewaters.

As mentioned previously, there is legislation now pending in Congress (H.R. 11302) which if passed in its present form would require EPA to establish supplemental standards or treatment guidelines for water reclamation and potable reuse within nine months of enactment.

Present Drinking Water Regulations

Under the 1975 NIPDWR maximum contaminant levels (MCL's) are set for ten inorganic chemicals, six organic chemicals, turbidity, and coliform bacteria. Briefly summarized, these MCL's are:

Maximum contaminant levels for inorganic chemicals

Contaminant	Level, mg/l
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Fluoride	1.4-2.4
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

Maximum contaminant levels for organic chemicals

Contaminant	Level, mg/l
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro - 6,7-epoxy-1,4,4a,5,6,7,8, 8a-octahydro-1,4-endo, endo-5,8 - dimethano-naphthalene)	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer)	0.004
Methoxychlor [1,1,1-trichloro-2, 2 - bis (p-methoxyphenyl) ethane]	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-technical chlorinated camphene, 67-79 percent chlorine)	0.005
(b) Chlorophenoxys:	
2,4 - D, (2.4 - Dichlorophenoxyacetic acid)	0.1
2,4,5 - TP silvex (2,4,5-trichlorophenoxy-propionic acid)	0.01

The MCL for turbidity is one turbidity unit (TU).

The MCL for coliform bacteria is one per 100 milliliters.

The new standards no longer contain specific reference to use of "the best available source of supply" but they do encourage the conduct of sanitary surveys on a systematic basis. Inspection of the source of supply is an important part of the sanitary survey. This means that treated wastewater probably will continue to be limited to a maximum of about 5 or 10 percent of the total supply and must still be subject to dilution, storage, and other natural purification processes before it reaches the point of withdrawal for water supply purposes.

The EPA Advisory Committee on the Revision and Application of the Drinking Water Standards (1973) states, in this regard, as follows:

"Experience has established the validity of these Drinking Water Standards in protecting health for water taken from natural sources. The

recommended revisions improve on the existing standards in several important ways, but the Committee reiterates that there is no claim that compliance with the revised standards gives full assurance of safety when the supply is other than a natural source. In particular, the revised standards are not intended for the ultimate reuse of municipal wastewater as a direct source of public supply for human consumption with little or no intermediate dilution."

"It is the opinion of the Advisory Committee that a national research program must be conducted before specific standards governing the conversion of municipal wastewater to drinking water are formally considered. Such research is long overdue to provide knowledge of all specific substances, organic and inorganic, in sewage treatment plant effluents, and to permit the development of more sensitive analytical methods for their detection. These substances would then be evaluated for public health significance and treatability."

<u>Proposed EPA Regulations for Control of Organic Contaminants in Drinking Water</u>

These proposed regulations are now out for review and comment. They contain two parts. Part I would set a MCL of 0.10 mg/l (100 ppb) for total trihalomethanes including chloroform. Part II would prescribe the use of granular activated carbon (GAC) treatment technique where synthetic organic pollution is a problem. There are three criteria which GAC systems would be designed to achieve under the proposed regulations:

1. The concentration in the effluent of any of the volatile halogenated organic compounds (except for trihalomethanes) determinable by the purge-and-trap/gas chromatography method shall not exceed 0.5 μg/l;

2. The removal of influent total organic carbon with fresh activated carbon shall be at least 50 percent; and

3. The effluent total organic carbon may not exceed the value with fresh activated carbon by more than 0.5 mg/l. Of course, the design must also assure that the requirements specified in the interim primary regulations are also met, including THM concentrations, disinfectant demand and concentrations of other regulated chemicals.

The initial impact of these proposals would fall principally on the large cities. A group of large cities in AWWA is protesting the adoption of these new regulations. They contend that such regulations should not be adopted until further research determines that trihalomethanes and synthetic organics are actually carcinogenic in humans at the concentrations which they appear in drinking water, and, if they are determined to be carcinogenic in these concentrations, to determine the most appropriate threshold level so that a MCL can be established.

What effect, if any, the resolution of this controversy will have on wastewater reuse is problematical.

The potential carcinogenic effects of trace organics depend upon long-term (20 years or more) ingestion of certain organics in drinking water. For military purposes the criteria should be such that the total combined exposure of individuals in military service and in civilian life to trace organics is not excessive.

Attitudes and Policies of Organizations and Agencies Toward Wastewater Reuse for Potable Purposes

Attitudes in this regard range from active opposition, to indifference, and moderate encouragement.

One great problem with the reuse of renovated wastewaters for drinking is that it is almost never seriously considered except as a last resort when no alternatives exist. When this point is reached, that is, when the choice is the use of reclaimed water or no water, then acceptance comes readily. Water reuse is less painful than the economic or physical hardships attendant to lack of water; and the risks involved, if any, become readily acceptable to the persons directly involved. Then the problem becomes one for the persons faced with the necessity for water reuse to gain approval of a regulatory authority in some distant place, far removed from the problem. This is a very difficult task. To date little success has been enjoyed in this respect. The need for reuse will probably always remain localized, but as fresh water resources are more fully used, there will be an increasing number of places where reuse will become an obvious answer to water shortages. When this happens, it would be good if renovation techniques, process control, and monitoring procedures were to be fully developed, proven, accepted, and awaiting use to provide dependably safe supplies of water recovered from wastewater. With the increasing pollution of existing public water supply sources by wastewater discharges and runoff, many, if not all, of the treatment and quality conditions of wastewater reuse are being approached in existing water works. If as much concern develops about these water supply problems, and if there is as much insistence on fail-safe water systems as now exists for fail-safe wastewater renovation, then there is some hope that the necessary scientific and engineering skills will be available for future successful wastewater reuse.

AWWA Policy--
Currently the American Water Works Association has under consideration and review a revised policy on the "Use of Reclaimed Wastewater as a Public Water Supply Source", as follows: "Recognizing that properly treated wastewater constitutes an increasingly important element of total available water resources, the American Water Works Association urges the federal government to support an immediate and sustained multidisciplinary research effort to provide the scientific knowledge and technology necessary to the future use of reclaimed wastewater as a public water supply source with full protection of public health."

"In the development of such effort these factors are important:

"1. Ever increasing amounts of treated wastewater are being discharged to the waters of the nation and constitute an increasing proportion of many existing drinking water supplies."

"2. A growing number of proposals are being made to introduce reclaimed wastewater directly into various elements of domestic water supply systems."

"3. The sound management of the total available water resources may include consideration of the potential use of properly treated wastewater as part of drinking water supplies."

"4. Insufficient information exists concerning acute and long-term effects on human health of such wastewater uses."

"5. Fail-safe technology to assure the removal of all potentially harmful substances from wastewater is not available."

"6. Any advocacy of the direct use of reclaimed wastewater as a public water supply source must await the development of the necessary scientific knowledge and treatment technology."

In AWWA, a policy of this kind may originate in a technical committee. It then must be approved or replaced by the Technical and Professional Council, and then adopted by the General Policy Council. As a report or proposed policy progresses in AWWA it may be approved, revised, or discarded and replaced by each higher echelon of authority. This means that the policy is subject to administrative and political considerations in addition to the purely technical ones which may have been influential in the initial stages. The final decision rests entirely with the General Policy Council, subject to vote of the Board of Directors.

EPA Policy Statement on Water Reuse--
"The demand for water is increasing both through population growth and changing life styles brought about by advancing technology, while the supply of water from nature remains basically constant from year to year. This is not to imply that we are or will shortly be out of water, although water shortages are of great concern in some regions. Rather, we must recognize the need to use and reuse wastewater whenever possible. Therefore,

1. EPA supports and encourages the development and practices of successive wastewater reclamation, reuse, recycling and recharge as a major element in water quality management, providing the reclamation systems are designed and operated so as to avoid health hazards to the people or damage to the environment.

2. EPA recognizes and supports the potential for wastewater reuse in agriculture, industrial, municipal, recreational, and groundwater recharge applications.

3. EPA does not support the direct interconnection of wastewater reclamation plants with municipal water treatment plants.

4. EPA will continue to support reuse research and demonstration projects."

"The concurrent use of the Nation's rivers and lakes for both municipal water supply and waste disposal has been practiced for many years in many areas of the country. It is estimated that 50% of the Nation's population now derives their water supply from surface sources which have also received a variety of industrial wastes, untreated sewage, urban runoff and effluent from a variety of sewage treatment plants. Public health officials have relied upon time of travel or storage and treatment to protect the public against infectious diseases and toxic substances. Water quality standards and treatment requirements applicable to surface sources used for water supply permit the discharge of relatively high quantities of wastes."

"Indirect reuse for municipal public water supply is a fact of life; however, direct reuse is a new matter requiring careful research and investigation before introduction."

"Health problems in a direct interconnection or in a recycling situation relate to viruses, bacterial build-up, chemical build-up, the possibility of accidental spills or sabotage and a questionable record of reliability in the operation of wastewater treatment plants. Viruses are difficult to identify and measure and are more resistant to disinfection than bacteria. Carbon columns and other possible advanced waste treatment elements may harbor bacteria and contribute to the development of unhealthful levels of bacteria in a recycling situation."

"The direct introduction of chemicals from a waste-stream and their build-up through potable system-waste system recycling can present increased long-term chronic hazards, presently undefined. Accidental spills or sabotage present an acute threat which cannot be disregarded, as anyone can throw anything down the drain; some system of holding and dilution reservoirs may need to be provided between the reclamation plant and the potable water intake together with biological and chemical monitoring." (Note: This would not apply to military in field operations.) "With regard to the reliability of reclamation plant operation, studies in California have shown that 60% of wastewater treatment plants studied had some breakdown during the year. Observations of engineers and others confirm that reliability is a common problem in wastewater treatment plants; safeguards must be provided to prevent the introduction of non-treated or poorly treated wastes into a potable water system."

For the above reasons, EPA does not support the direct interconnection of wastewater reclamation plants with municipal water treatment plants."

World Health Organization--
In 1973 WHO issued a Report of a WHO Meeting of Experts entitled, "Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards".

This report contains the collective views of an international group of experts and does not necessarily represent the decisions or the stated policy of the World Health Organization. However, the expert technical views expressed may be of interest.

Some excerpts from the WHO report follow:

"The Meeting of Experts was convened for the purpose of reviewing and evaluating: the extent of the reuse of wastewater, whether intentional or unintentional; the specific health hazards associated with the reuse of wastewater for agricultural, industrial, recreational, and domestic purposes; and the latest technological developments in treatment. The Meeting was also asked to make recommendations on the research needed on wastewater treatment and on the health safeguards to be observed in the reuse of effluents for various purposes."

"WHO's International standards for drinking water gives maximum limits for 6 toxic substances and specifications for 18 substances or characteristics affecting the acceptability of water for domestic use. It may be thought that these drinking water standards apply only to relatively pure and protected water sources and that more rigorous chemical criteria would be necessary to evaluate renovated wastewater prepared for eventual domestic consumption. However, the Meeting pointed out that a high proportion of existing surface water supplies throughout the world are so heavily contaminated with municipal and industrial wastes as to make the health risks associated with the drinking of water derived from such sources only slightly different from those involved in the direct reuse of wastewater."

From the WHO report Summary and Recommendations:

"Whenever the intentional direct or indirect reuse of wastewater is planned or becomes inevitable, the following conditions should be ensured:

"1. Water quality standards appropriate to the reuse should be formulated and rigidly enforced."

"2. As a guide to governments wishing to formulate national standards, international agencies such as WHO and FAO should develop reuse standards for various purposes, including food preparation and the watering of agricultural crops."

"3. Full knowledge should be maintained of each water source whatever it may be, whether a natural body of water or wastewater, so that treatment may be adequately designed to allow for possible fluctuations in quality, account taken of potential health risks, and adequate safeguards taken to ensure the safety of workers and consumers."

"4. Laboratory facilities should be adequate to undertake the programme of monitoring and testing appropriate to the proposed water use. For certain complicated test procedures, involving special skills and equipment such as are needed to identify

viruses or traces of certain organic materials, it may be sufficient to provide facilities on a regional or area basis."

"5. Reuse systems should be designed by well qualified engineers experienced in such new treatment processes as chemical coagulation, high-efficiency filtration, carbon adsorption, reverse osmosis, and ion exchange, appropriate combinations of which make it possible to reduce nearly all contaminants in wastewater to concentrations found in natural unpolluted sources. The operation and supervision of these systems should be entrusted to highly trained personnel."

"6. The safe disposal of sludges, slurries, and brines, which may be highly dangerous to handle, should be taken fully into account both at the design stage and in operation."

"Existing natural sources of drinking water in several parts of the world already contain industrial and municipal wastewater in proportions that may approach 100% in periods of low flow. The degree to which this unintentional and indirect reuse affects existing sources should be determined and appropriate measures should be taken, particularly in critical areas, to ensure the safety of drinking water."

CURRENT RESEARCH IN WASTEWATER REUSE AND CRITERIA DEVELOPMENT

The pace and the success or failure of current research being done by others can have significant effects on military efforts to produce water quality criteria for the reuse of renovated wastewater for potable purposes at minimum cost and within the shortest time frame.

Major research in the technology of reuse is being conducted primarily in the United States, South Africa, and Israel, with some work being done by the World Health Organization in developing nations.

Most readers of this report are familiar with the results of research and development work currently underway. However, it appears that a great deal of significant information will be forthcoming from many sources over the next few years. Current events and new developments, particularly in the assessment of numerous full-scale projects now in operation, should be followed closely for possible application of the results obtained to potable reuse of wastewater by the military service.

APPROACH TO ESTABLISHMENT OF WATER QUALITY CRITERIA FOR POTABLE REUSE

Who Must Be Satisfied?

In addition to official approvals within the armed services, there are a number of outside civilian agencies which have an official or unofficial concern with quality criteria for potable use. Their views on the safety of proposed criteria will have some direct or indirect bearing on both official and general public acceptance of the criteria. Outside the U.S., the military services would probably have complete control over

potable reuse policies and criteria, although it would be reassuring and helpful to have NAS (National Academy of Sciences) concurrence in the protocols used in criteria development and the scientific objectivity, thoroughness, and competency of studies carried out to reach the criteria. Within the U.S., the U.S. EPA and the various State water agencies probaby will have some official involvement in approval for fixed military establishments. At any rate, their intense concern with the matter of reuse criteria, whether their official approval is required or not, and the great influence of their opinions on public reaction and acceptance make their approval important. There are many other agencies, most of which have no official responsibility or control over water reuse criteria and which are interested in the criteria that may be adopted by the military only from the standpoint that the military criteria may have an indirect effect on civilian criteria or reuse policies. These agencies include: The Conference of State Sanitary Engineers; U.S. Department of Interior; the Food and Drug Administration; the American Water Works Association; the National Institutes of Health; the Department of Health, Education, and Welfare; the National Aeronautics and Space Adminstration, and the American Public Health Association.

How Can Interested Agencies be Satisfied?

Securing necessary official approval and unofficial public approval of water quality criteria for potable water derived from wastewater is an extremely difficult and very complex undertaking. Previous attempts in this regard and the current controversy between EPA and AWWA concerning trace organics in drinking water furnish valuable guidance both as to things which must be done as well as some pitfalls to be avoided.

It is quite clear that the key to acceptance of wastewater reuse is the declaration by a recognized and respected scientific authority to the point that reuse is safe from a health standpoint. It is apparent that current doubts and disagreements about reuse are not going to be resolved in the administrative and political arenas without prior expression of strong favorable technical opinion.

What are the Principal Areas of Health Concern?

There are four major areas of concern with respect to possible health effects from potable reuse of renovated wastewawer. They lie in the fields of bacteriology, virology, and toxicology and in the reliability of treatment plant operation.

Who Should Develop Criteria?

Ultimately, water quality criteria for potable reuse eventually must be considered, reviewed, and approved or accepted by large numbers of agencies and groups. However, the specific task of developing criteria can best be done through intensive work by a very small group of the top experts in the highly specialized areas of concern. This group should be composed of not more than 3 to 5 persons. It could be made up of a bacteriologist-virologist, a toxicologist, and a sanitary engineer. Each

should be a nationally recognized expert in his field, and should, in addition, have some knowledge in the other fields as well as familiarity with drinking water and health.

The group must be kept small in order to get the job done. Past efforts to produce criteria by large committees or panels have failed, due in large part to the necessarily long time required for large groups to accomplish anything and the difficulty of securing unanimous approval of anything by a large group of people.

It is doubtful that criteria developed within one of the regulatory agencies will find wide acceptance by others in a reasonable period of time, if ever. Criteria should be developed by a party not involved in present controversies. There is one technical agency, the National Academy of Sciences, whose scientific judgment and expertise is universally respected. Approval of procedures followed in producing criteria should be obtained from NAS prior to review by other groups or agencies.

Suggested Task Group

It is recommended that the armed services employ a task group made up of three individual consultants and that staff support for the task group be provided by a consulting firm. The supporting staff services would include secretarial work, technical editing, and the mechanical production of the task group report. Without formal provision of adequate staff support, the task group will probably not produce a satisfactory report. The Water Quality Task Group would be selected by the military sponsors and employed by them. Each Task Group member would be approved by NAS prior to initial contacts with any of them. The Task Group should consist of a virologist-bacteriologist, a toxicologist, and a sanitary engineer (with experience in water quality criteria development). These people must be chosen from the top experts in the country. Criteria development will require several weeks of effort by the Task Group. To get the persons with the best credentials to do this work, it is doubtful that they can be expected to devote full time to the task. The most practical way for them to work probably will be part time in connection with their regular duties. This means that several months must be allocated for completion of the work by the Task Group. Definite time schedules should be established. The Task Group should meet at quarterly or monthly intervals for discussion of work accomplished and future chores during development of the criteria. These meetings should also be attended by representatives of supporting staff, the military, and NAS. Again, it is desirable to limit the representation to one for each agency in the interest of efficiency and progress.

The specific assignment of the Task Group would be to develop proposed water quality criteria for potable use of renovated wastewaters within a definite time limit.

The proposed criteria could take the form of maximum contaminant levels or treatment technique requirements, or a combination of the two. They could include non-conventional as well as conventional criteria.

The Task Group should also recommend new process control measures and finished water monitoring procedures where such innovations appear to be necessary. With respect to organics, it is not possible, within any reasonable time period, to determine the safe limiting concentration for each of the hundreds of organic substances which may be present in water. Therefore, it is necessary to establish an overall limit on some measure of total organics which will provide an acceptable level of risk with respect to potential health effect of organics. If the Task Group cannot set an overall limit on organic substances, then it may be possible to prescribe certain minimum treatment requirements. Treatment techniques to be considered could include: carbon adsorption, UV-ozonation, ultrafiltration, reverse osmosis, ion exchange, and various combinations of these and other unit processes.

With respect to virus, it may be better to rely upon certain specified pre-treatment and disinfection procedures, rather than upon the analysis of finished water for detection of the organisms, because of the difficulties of concentration and uncertainties of isolation, and the length of time required to complete virus tests.

It may be advantageous to extend the use of specified treatment in lieu of numerical standards to areas in addition to virus and trace organics (granular activated carbon) as previously suggested.

There are direct tests and established limits for most toxic substances of concern including heavy metals, insecticides, and herbicides. However, some search should be made by the Task Group for a rapid overall test to be applied to finished water to determine its freedom from toxic substances.

"Rapid Tests for the Detection of Toxic Materials in Water" is the title of an article published, April 1953, by the AWWA in a Willing Water Supplement (No. 21). It contains rapid methods of testing for antimony, arsenic, barium, organic contamination (chlorine demand), chromium, cyanide, and dithizone metals.

All of the efforts of the Task Group should be carried out with the objective of producing criteria by methods which will be accepted by the NAS, because NAS concurrence must be obtained before other groups and agencies are approached.

Possible Alternatives to Preparation of Criteria by Special Task Group

As one alternate to preparation of criteria by a special task group selected and working for the military and then seeking NAS approval of methods used, it might be possible to contract directly with NAS to prepare the criteria. The NAS presumably would do the work with their staff plus advice or assistance from consultants of their selection. This has the advantage of built-in acceptance of the criteria by NAS if they actually would agree to do the work and to set criteria. It has the disadvantage that it may be more difficult to expedite the work and to be assured of timely completion than if a Task Group with all members responsible to the military is employed.

A second alternate to preparation of criteria by a special task group is to contract with an individual consultant or a consulting firm to draft the criteria. This approach may be the most efficient for producing a set of criteria but the criteria may not be as readily accepted as if the origin were a special task group or the NAS. This is difficult to assess. Once criteria are proposed, they will be subjected to extremely close scrutiny and many questions as to their validity will be raised, regardless of their origin. Much criticism will be based on the fear that development and approval of military criteria may be the opening wedge to their acceptance for civilian purposes. This is one reason that many agencies not having official review privileges for military water reuse criteria will have a keen interest in the matter, and will be offering unofficial advice.

Military VS. Civilian Requirements for Reuse Waters

It must be emphasized to those charged with development of criteria that military conditions differ substantially in many respects from civilian conditions with regard to wastewater reclamation and reuse. These differences, in general, make criteria development less difficult for military purposes because of better controlled conditions and restricted variability.

With respect to potable reuse in the military, there are also important differences affecting reuse criteria which must be taken into account. Actually, there are three categories of potable reuse conditions:

1. Potable reuse of renovated wastewater by troops in the field is not contemplated at this time.

2. Potable reuse is a possibility at advanced/remote bases to support military operations in the field over relatively short periods of time.

3. Potable reuse is also considered for semi-permanent Navy bases outside of the U.S. where desalination is now required, and at some fixed military installations in the U.S. which are located in water short areas.

The conditions of reuse for the last category are quite similar to those for the general public. Reuse at advanced/remote bases (second category) may be carried out under somewhat more favorable conditions. For example, wastewater composition is better known and more easily controlled than under municipal conditions. It may be possible to select and separate various sources of wastewater under military conditions, while this is not usually practical in most municipal systems. The length of exposure of military personnel to reclaimed water may be for relatively short periods of time, and the term of exposure may be subject to control. The population to be exposed to wastewater reuse is subject to control, and it may be possible to exclude from such use persons who are especially susceptible to disease or other potential ill effects from drinking water because of age or infirmity. Refugees and wounded are two examples of groups of people who could be excluded.

These differences should be taken into account in future development of criteria.

RESEARCH AND OTHER WORK NEEDED TO DEVELOP OR GAIN APPROVAL OF QUALITY CRITERIA

Background

Again, quoting the report referred to earlier, the WHO experts summarized (1973) research needs for water reuse as follows:

"Further research is required in the following areas, in which the present state of knowledge is known to be insufficient:

"1. The potential long-term health effects of trace materials and residues remaining after conventional water treatment. Research on this topic should include both physiological investigations on individuals known to have been using drinking-water derived from polluted sources and toxicological studies on the waters themselves under laboratory conditions."

"2. The improvement of methods of identifying, measuring, and monitoring chemical and microbial pollutants. Rapid identification of bacteria and viruses is required, and there is a need for a means of monitoring chemical pollutants by simple field tests, without the use of expensive equipment and highly qualified analytical staff."

"3. The development and improvement of treatment and separation processes suitable for use in many parts of the world. The reliability of treatment processes should be increased, and a more accurate determination should be made of their capabilities, separately and in combination, to remove different types of contaminant in varying concentrations."

In 1975, in an effort to identify research priorities and to provide EPA with direction for conducting its municipal wastewater potable reuse research program, EPA, AWWA, and WPCF (Water Pollution Control Federation) conducted a workshop at Boulder, Colorado.

The workshop was three days in length and was designed for persons involved in the use, conduct, direction, or specification of research in the wastewater renovation and reuse field. WPCF and AWWA, and selected representatives of federal, state, municipal, industrial, academic, and consulting organizations participated. In addition to presentations on specific reuse situations that included both native and foreign experience, papers were presented on (1) potential health hazards of using wastewater for domestic purposes, (2) the status of existing technology that can be used to properly treat wastewater for reuse, and (3) the socio-economic aspects of reuse. The presentations established the state-of-the-art, or "where we are now".

The findings of this workshop were summarized in a paper entitled, "Research Required to Establish Confidence in the Potable Reuse of Wastewater", by John N. English (EPA), K. D. Lindstedt, and Edwin R. Bennett at the 1975 WPCF meeting in Miami, Florida.

The research needs associated with the potable reuse of municipal wastewater was identified under six categories: (1) Treatment, (2) Treatment Reliability and Quality Control, (3) Health Effects - Inorganics, (4) Health Effects, Organics, (5) Health Effects - Biological, and (5) Socio-Economics Aspects.

The conclusions of the workshop were summarized by English, et al, as follows:

"It is anticipated that a program undertaking the research previously described will require a minimum of 10 to 15 years of intensive work to develop sufficient information to clearly define meaningful standards that can be applied with confidence to potable waters derived from a polluted source. These standards will have to be based on realistic public health considerations and have the support of public health officials at all government levels."

"The goals of a direct or overt potable reuse program are similar to those of the present EPA Health Effects and Water Supply programs which have recently identified organic materials having potential health hazards in many of our nation's drinking waters. Some of these supplies contain appreciable quantities of wastewaters, and their use for domestic purposes can be classified as an indirect or covert form of potable reuse."

"There was a general consensus of the workshop attendees that the research identified must be addressed by both water supply and wastewater organizations. Even if direct reuse is not implemented, all the same questions which have been raised must be answered, and the technology must be developed to remove potential health hazard constituents present in our water supplies."

"Any program of the magnitude required to alleviate the health concerns of both overt and covert potable reuse is not a local or even a national undertaking. International coordination is necessary since other nations such as South Africa, Israel, and some in the European community are facing deteriorating and unreliable water supplies, and are actively researching the problems involved with covert and overt potable reuse."

"The research identified at the workshop will be used to lay out a long range approach which will utilize the results from the ongoing EPA Wastewater, Health Effects, and Water Supply Programs. By clearly defining a strategy for potable reuse the results from these programs can be used as 'stepping stones' for a future potable reuse research program."

These two views of research needs are typical of the time (1973-1975) with regard to municipal reuse. Current views probably do not differ greatly

from these, although the organics problem is now recognized as being a potential problem for all public water supplies regardless of source of supply, and the problems of trace organics in existing polluted sources of supply is considered by many health authorities as being a greater problem than it was thought to be four or five years ago.

Present Specific Needs for Military Reuse

To quote the Contract Request For Quotations, it is "the desire of the Government to utilize existing standards, criteria, rationales, protocols, and data as much as possible in order to minimize new research requirements and thus minimize the time and dollar requirements of the project".

To approach the question of research needs in this manner, it may be useful to recapitulate the main areas of concern and various methods for meeting these concerns.

The principal areas of concern in wastewater reuse are: (1) bacteriology, (2) virology, (3) toxicology, and (4) treatment plant reliability. Methods for solving problems in one or more of these areas of concern include: (1) source control of contaminants, (2) specified treatment techniques with process control and monitoring, and (3) quality criteria (MCL's) and monitoring of finished water.

Bacteria--

Consideration must be given to presently accepted practices and procedures in the water works field which may be applicable in some way to wastewater renovation. For example, the results of bacteriological tests of potable water samples are not known until after the water has been distributed to customers and consumed. In other words, the bacteriological quality of the water is not definitely confirmed by actual test at the time of processing. Rather, reliance is placed upon one of two things: (1) historically satisfactory bacteriological quality of water at the source, especially for ground waters, or (2) provision for continuous disinfection with processes and under conditions known to produce coliform-free water, as for most surface waters. The bacteriological tests, if negative, provide a record of the good quality, but, if positive, are rather a late warning. Loss of chlorine residual or a rise in turbidity, if observed, may give an earlier warning of possible bacteriological trouble. All of this has been accepted as good water works practice for the past 50 years, and no serious health consequences have resulted. If an instantaneous means were developed for detection of coliform organisms, it would be comforting but might not produce any great improvement in the bacteriological quality of public drinking water supplies.

Producing bacteriologically safe drinking water from wastewater may differ slightly from that just described for conventional water supply sources. Depending upon the degree of wastewater pretreatment provided, wastewater sources may contain higher concentrations of bacteria and have greater chlorine demand due to the presence of ammonia or other substances. However, by providing proper initial mixing of the chlorine,

by proper pretreatment, and by any necessary increase in chlorine dosage or contact time, a coliform-free water can be produced from wastewater even in the presence of ammonia. One example of this is the experience at the South Tahoe Public Utility District AWT plant where water has been produced from wastewater for unrestricted recreational purposes for the past 8 years. The water met the Drinking Water standards for bacteriological quality (but source of supply did not meet DWS) for 8 years. It is particularly noteworthy that for the 21-month period of November, 1974 to August, 1976 all of the 602 consecutive daily bacteriological samples were found to be free of coliform organisms. During this period of record, chlorination was done in the presence of ammonia. In 1977 and 1978 breakpoint chlorination was practiced a good part of the time.

The experience with bacteriological quality in operation of another AWT plant, Water Factory 21, in Orange County, California has been even better than at Tahoe. Here again, part of the time disinfection has been carried out in the presence of ammonia; at other times, breakpoint chlorination was practiced.

The question of chlorine demand and reduced germicidal effectiveness in the presence of ammonia always arises in connection with wastewater renovation. It appears from recent good experience with chlorination in the presence of ammonia, that there is still much to be learned about chlorine-ammonia treatment. It also may be that the importance of pH as it affects the speed of chloramine formation and the importance of initial mixing may not have been given sufficient weight in early studies of chlorine-ammonia treatment. Additional research in this area may be warranted.

The 1977 NAS report on Drinking Water and Health states: "Current coliform standards are not satisfactory for water reclaimed directly from wastewater. Meeting current coliform standards for water reclaimed directly from wastewater, or for water containing several percent of fresh sewage effluent is insufficient to protect public health. For such raw water supplies, additional new microbiological standards should be developed and applied as a supplement to coliform standards."

To meet this concern, attention must be given to supplemental standards, which might include fecal coliform standards, or total plate count requirements, or other additional safeguards. This probably can be done without the necessity of developing new laboratory procedures.

Virus--

The situation with respect to virus in water purification and in wastewater renovation is a close parallel to that regarding bacteria. However, in virus inactivation, final dependence rests entirely upon disinfection under proper conditions for production of virus-free water from any source. Virus recovery procedures are constantly and rapidly improving, but there are some viruses for which there is no method of recovery. Except for a few water works in the largest cities, virus tests are not run routinely on public water supplies; reliance is placed upon proper operation of disinfection facilities to assure safety from virus. There is not a great deal of information available on viruses in public water supplies.

In the October, 1969 Journal AWWA a Committee report by Clarke, Berg, Liu, Metcalf, Sullivan, and Vlassoff summarized very well and completely the status of viruses in water at that time. Excerpts from this report follow:

"There is no doubt that water can be treated so that it is always free from infectious microorganisms-it will be biologically safe. Adequate treatment means clarification (coagulation, sedimentation, and filtration), followed by effective disinfection. Effective disinfection can be carried out only on water free from suspended material." The Committee concluded that for most effective disinfection they felt it would be best to keep the turbidity as low as 0.1 Unit, as recommended by AWWA water quality goals. With turbidities as low as 0.1 to 1, they concluded that a pre-plant chlorine feed need be only enough to have a 1 mg/l free chlorine residual after 30 minutes contact time. Postchlorination practice would then depend upon the ability to maintain such residuals throughout the distribution system. Thus, the disinfection of water is dependent upon optimizing the unit processes of chemical coagulation, sedimentation, and filtration (which in themselves provide substantial reductions in bacteria and viruses) to produce minimum water turbidities to assure the maximum contact between any remaining pathogens and the disinfectant added.

The experience with virus removal in AWT has been good, even with chlorination in the presence of ammonia. However, viruses have been isolated on a few occasions at Water Factory 21 and in research at Pomona, California.

As with bacteria, it appears that water works practice in virus inactivation can be safely transferred with few modifications to wastewater renovation. There is a known set of treatment conditions that historically has provided drinking water with acceptable virus quality. However, there probably is more question about chlorine-ammonia treatment in the case of virus than with bacteria.

Chlorine-ammonia disinfection has an advantage over free chlorination which is similar to that provided by ozone and chlorine dioxide in that use of ammonia with chlorine limits or stops trihalomethane production. The free chlorine reacts first with the ammonia to produce chloramines. The chloramines do not react with organics, thus limiting trihalomethane production. It may be worthwhile to conduct new studies of virus inactivation by chlorine-ammonia treatment for several reasons. One would be to compare its trihalomethane production with that of other disinfectants. A second reason would be to determine over a range of pH values and under different conditions of initial mixing the rates at which three different chlorine reactions are completed during (1) virus inactivation, (2) chloramine formation (complete loss of free chlorine), and (3) trihalomethane formation. It appears that with proper initial mixing, the inactivation of virus by adequate doses of free chlorine may take only a few seconds or a few minutes. The complete conversion of chlorine to chloramine is very pH dependent. At pH = 8.3 and at 25^{o}C, one study indicates that 99 percent of the chlorine will be converted to chloramine (if ammonia is

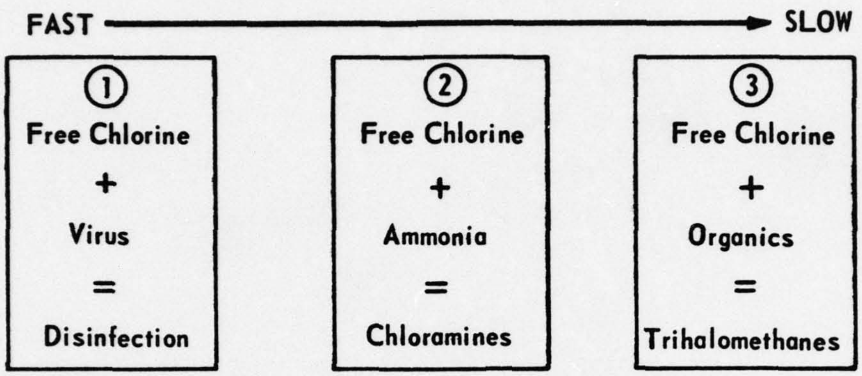
present) in about one minute, however, at pH = 11.0 the required time is about 90 minutes, and at pH = 5 is about 210 minutes. Thus, it is possible with good mixing at certain pH values that virus inactivation might be accomplished by free chlorine before it has completely reacted with the ammonia. The chlorine-organic reaction which form trihalomethanes are notably slow and may require hours or even days for 100 percent completion. This means that the chlorine-ammonia reactions may be completed in time to limit or prevent trihalomethane production. The relative reaction rates are illustrated by Figure 4.

Because it may not be desirable to completely remove ammonia from all wastewaters, it may be important to further investigate chlorine-ammonia treatment in the light of today's changed conditions. The changed conditions from the time that early studies were done include the trihalomethane question and the development of new knowledge concerning the extreme importance of initial mixing of water and the applied chlorine to the rate of disinfection. The importance of the initial mixing of chlorine and the water being treated must not be overlooked. It is the single most influential factor in good disinfection. This is one operation that usually can be done better in actual plant operation than it is done in the laboratory. If laboratory mixing of chlorine and water is done by stirring with a stirring rod or paddle, by shaking in a flask, or even by back-mixing with a mechanical stirrer, the laboratory results may be completely worthless for comparison to results which are obtained in a well-designed instantaneous tube-mix in a treatment plant. Further, in laboratory work chlorine should be added to water containing virus and ammonia. If, instead, virus is added to water containing ammonia and chlorine then the opportunity for virus contact with unreacted free chlorine is lost. The order of addition is important. There is not good information on exact procedures followed with respect to initial mixing and order of addition in some of the early chlorine-ammonia studies.

Because the efficiency of virus inactivation by chlorine in the presence of ammonia and organics will undoubtedly be questioned, it would appear that literature review and research in this area should have high priority. The information developed will also be valuable in water purification practice.

Demonstrated accepted virus inactivation by free chlorine in chlorine-ammonia treatment rather than by free residual chlorination per se could greatly reduce the costs of wastewater renovation.

Research should be continued with various active ozone species for virus inactivation. Better definition of the mechanics and kinetics of ozone in water and wastewater is needed to establish time-concentration relationships which will assure the desired results in the field. Ideally, an ozone disinfection process can be developed which will give results so uniform that use of a specified ozone treatment technique will be accepted as evidence of good biological quality. Some further confirmation for record purposes could be afforded by use of the latest concentration-isolation procedures for virus recovery and identification. This treatment technique with test follow-up would correspond to presently



Reaction (1) may be complete before Reaction (2) occurs.
Completion of Reaction (2) may limit or prevent Reaction (3) .

Figure 4

POSSIBLE RELATIVE REACTION RATES

accepted practices with regard to bacteriological quality in the water works industry. Also, research should be done on possible formation of harmful organic by-products in ozonation.

Toxic Substances--
As described previously, the NIPDWR specify MCL's for ten inorganic chemicals and six organic chemicals. Monitoring and analytical requirements for public surface water supplies consist of annual sampling and analysis for the inorganic chemicals and sampling and analysis at three-year intervals for the organic chemicals. The requirement for tests at such infrequent intervals indicates that once the safety of supply with regard to these elements is established that major variations in content are not expected. It would appear that similar test procedures could be applied to wastewater renovation. As in the case for fresh water sources, if there is reason to suspect that changes have occurred, more frequent sampling could be demanded. The military is in a better position than most cities to exercise source control over many toxic materials entering wastewater.

For most of the toxic substances (not including nitrate) for which MCL's are set in the NIPDWR, the limits are based on no ill effect for lifetime "exposure" to water not exceeding the limit set.

It is appropriate at this point to quote again from the report of the EPA Advisory Committee on the Revision and Application of the Drinking Water Standards:

"Waters reclaimed from treated community wastewater as a source received considerable discussion. Treated domestic, industrial, and other wastewaters may contain many substances not significantly present in natural waters and are not included in these Standards. Such substances in sufficient concentrations could be hazardous to health or otherwise objectionable. It is not possible, at this time, to identify the constituents of potential concern, much less set limits therefor. Moreover, limits for innumerable substances would require an impossible burden of analytical examination."

The Committee is no doubt correct in its assessment that standards and tests for all constituents of potential concern present an impossible condition to satisfy. If it is also correct in its contention that the toxicity standards do protect conventional water supply sources, including badly polluted ones, but do not adequately protect water produced by wastewater renovation, then a difficult problem is presented. It seems quite likely that more comprehensive toxicity criteria will need to be applied to evaluation of renovated wastewater than the criteria now used for public water supply produced from conventional sources. It would seem that the only remedy would be the development of a field test for overall evaluation of total toxicity which would given an immediate readout of "safe" or "unsafe".

On-Line Monitoring of Toxicity--
Cytological assay has shown some promise. Difficulties with this approach include: the time required to obtain results; the possible lack of

sensitivity to unconcentrated renovated wastewaters; and adaptation to field handling. USAMBRDL has supported research in this area in the past, and may be in a position to evaluate the possible yield of further research along these lines.

The outcome of additional research to develop an on-line monitor for toxicity could be (1) successful, or (2) unsuccessful. Even if it is completely successful from a technical standpoint, some time will be required for the procedure to be accepted by the scientific community, and a longer time for political and public acceptance. If an on-line toxicity monitor is not developed, then questions can be raised about each of the hundreds of organic compounds which may be present in wastewater. Conceivably this could indefinitely delay acceptance of wastewater reuse by regulatory agencies.

Trace Organics--
The toxic substances which are most likely to be troublesome in renovated wastewaters are not the metals for which the NIPDWR specifies MCL's, but, rather, the organic compounds that are not removed by biological, physical, and chemical treatment processes.

Previous research supported by USAMBRDL has determined the total TOC and the fraction of volatile organic solutes in intermediate and produce waters from composite hospital wastewaters treated by screening, ultrafiltration, micro filtration, reverse osmosis, UV-catalyzed ozonation, and hypochlorination. These studies showed that volatile organics accounted for 13-73 percent of total TOC remaining after R.O., and 30-73 percent after ozonation. Five volatiles quantitated by the technique used were methanol, acetone, 2-propanol, diethyl ether, and methyl ethyl ketone. The fact that volatile organics make up a sizeable portion of the TOC in R.O. permeates, suggests that air stripping might be a candidate process to add to the treatment train. This suggestion is based on preliminary data which has been obtained at the Orange County Water District Water Factory 21 (WF 21). At WF 21, full-scale (15 mgd) plant tests were run using air stripping. The removals of certain selected organics and of chloroform and other trihalomethanes were measured. Some of the results are shown in Table 6.

TABLE 6
ORGANICS REMOVAL BY AIR STRIPPING, WATER FACTORY 21

Organic	Mean Percent Removal
Ethylbenzene	80
Chlorobenzene/o-xylene	60
1,3 Dichlorobenzene	80
1,4 Dichlorobenzene	90
1,2 Dichlorobenzene	70
1,2,4 Trichlorobenzene	50
Napthalene	40
Carbon Tetrachloride	95
PCB's	97
Trichloroethylene	98
Methylene Chloride	92
Chloroform	80

All methods for removing volatile trace organics are costly as compared to conventional water treatment. Air stripping is no exception, but might be worthy of laboratory investigation along with other methods for removing organics remaining in R.O. permeates.

Perhaps the most difficult area of research regarding potential health effects of renovated wastewater is the possible carcinogenicity of trace organics. As has been mentioned several times previously, this is a problem which is shared with all existing public water supplies.

In considering the question of trace organics and potential long-term health effects there are at least four possible approaches:

1. Limit reuse of renovated wastewaters for military purposes to those applications involving short-term use.

2. Attempt to select or develop a satisfactory measure of total organics in water, and to establish a MCL based on this overall parameter.

3. Try to select a specified treatment technique which would satisfy health concerns with regard to trace organics.

4. Supplement research already underway in the identification of the whole host of organics in water and find a MCL for each new organic identified. (This total task is a formidable one, and may never be accomplished.)

All public water supplies from both well and surface supplies contain organic matter. Many of the organic compounds have been identified, but the total number of trace organics numbers in the hundreds, and it will be many years, if ever, before all are identified.

Enough presumptive evidence has been gathered to arouse serious concern in public health circles. EPA officials have weighed the facts at hand and proposed a MCL for trihalomethanes and a granular activated carbon treatment technique for supplies containing synthetic organics.

Renovated wastewaters could meet the MCL for trihalomethanes quite easily. Experience at the Orange County Water District's Water Factory 21 has already demonstrated that their reclaimed wastewater is superior to many existing public water supplies with respect to trihalomethane content. The total trihalomethane concentration for WF 21 reclaimed water averaged 18 μg/l, compared to the average of 117.1 μg/l concentration found by the EPA in their recent national organic monitoring survey of drinking water supplies in 113 cities. Also, 18 μg/l is well below the proposed regulation limit of 100 μg/l for total trihalomethanes.

Further, treatment processes for wastewater renovation could quite readily include the granular activated carbon treatment which EPA has prescribed for water supplies polluted by synthetic organics.

As already seen, these two proposed regulations are being vigorously

opposed by operators of public water supplies which have polluted sources of supply on the basis that such regulations are unnecessary for health protection. The CSSE (Conference of State Sanitary Engineers) has also questioned the need for the proposed organics regulations. On the other hand, potential purveyors of reclaimed water would, in all likelihood, agree to meet the trihalomethane standard and, further, would provide the carbon treatment.

Regardless of the outcome of this controversy with respect to organics in water supplies, further resolution may be required with regard to renovation of wastewaters. The rationale behind the EPA proposal of a treatment technique as a remedy for the synthetic organics problem in water supplies strongly suggests that this may also be the best approach for wastewaters. The EPA originally set out to establish safe levels for each of the organics of concern. However, when it became evident that the number of these organics extended to many hundreds, the only practical solution which could be reached in any reasonable length of time was to use a specified treatment technique rather than to attempt to establish MCL's for each organic compound. This reasoning suggests that whatever effort is to be expended toward development of quality criteria for organics in renovated wastewater should be directed at a treatment technique rather than a standard for some measure of organics.

Summary of Specific Research Needs to Develop Quality Criteria for Military Reuse for Potable Purposes--
There are four areas in which research may facilitate development of quality criteria for renovated wastewaters to be used by the armed services for potable purposes. They are listed below in the order of priority, and are shown in Figure 5.

1. Specify or develop disinfection techniques to provide required virus removal (preferably techniques which are effective in the presence of ammonia).

2. Develop field test for overall evaluation of toxicity which will give immediate readout of "safe" or "unsafe".

3. Specify or develop treatment techniques which will satisfy health concerns with regard to trace organics. Consider granular activated carbon, membranes, and air stripping,

   OR,

   3a. Select or develop a satisfactory measure of total organics in water and establish a MCL for this parameter,

   OR,

   3b. Develop a rapid monitoring technique to assess carcinogenic effects of renovated wastewaters.

Figure 5

HEALTH EFFECTS RESEARCH

(In order of priority)

1. **VIRUS**

   Develop disinfection technique to provide required virus removal

2. **TOXICITY**

   Develop field test for overall evaluation of toxicity

3. **TRACE ORGANICS**

   Specify treatment techniques which will satisfy health concerns regarding trace organics

   or

   Select or develop satisfactory measure of total organics in water and establish MCL for this parameter

   or

   Develop rapid monitoring technique to assess carcinogenic effects of renovated wastewaters

4. **BACTERIA**

   Specify or develop disinfection technique to provide required bacterial removal

   or

   Develop rapid test for presence of Pathogenic bacteria

POTABLE CRITERIA

4. Specify or develop disinfection technique to provide required bacterial removal,

OR,

4a. Develop rapid test for presence of pathogenic bacteria.

It is very difficult to assess precisely the value of the successful completion of any one or all of these research projects toward development or acceptance of quality criteria for renovated wastewater. Certainly, if all were fully successful, the task should be much easier, but a positive result would not be assured, because opposition is based not only on technical considerations but upon emotional and political motivations as well.

<u>It may be entirely possible to develop potable reuse criteria without awaiting the outcome of ongoing or of future research.</u> These separate tasks should be pursued concurrently. As it has in the past, research will produce refinements in the standards which are constantly being updated and improved in the light of new knowledge, but there may be sufficient information already at hand to allow preparation of water quality standards regardless of source. The economics of meeting such standards is a separate question. There is certainly no reason that the military should not be a leader in developing potable water reuse criteria. A starting point is needed in criteria for potable water reuse wastewater. Even if the first set of standards is incomplete or unacceptable, some needed progress will be made by a serious attempt to develop such criteria.

RECOMMENDED PROCEDURE FOR DEVELOPMENT OF QUALITY CRITERIA FOR POTABLE WATER DERIVED FROM RENOVATED WASTEWATERS

<u>Narrative of Procedural Steps</u>

Upon completion of the Development Plan, the next step toward the goal of Potable Criteria is a decision by the military. This would consist of the selection of the type of contractor to be used for potable criteria development from: (1) a three or four man task group, (2) the NAS, or (3) a consultant. The second step would be to award a contract for criteria development. Military decisions would also be required regarding possible additional support of health effects research projects in the areas of: (1) disinfection of bacteria and virus, (2) toxicity, and (3) trace organics.

There are several tasks to be included in the contract for potable criteria development. These tasks would include a literature review of existing drinking water standards for water derived from conventional sources and related background studies, reports of health effects research, operating reports from existing wastewater reuse projects, latest treatment methods, new analytical and monitoring methods, objections to wastewater reuse, and related on-going research. The criteria development contractor would also evaluate treatment methods and specify

fail-safe techniques to be employed in renovating wastewater. Finally, the criteria development contractor would draft interim potable criteria which would include conventional numerical standards plus specified treatment techniques where advantageous. The contractor would also recommend operational and monitoring procedures with a view toward plant reliability and fail-safe operation.

During the time that criteria are under development, there would be in progress health effects research by the military, the EPA, universities, and other agencies. The criteria contractor should keep abreast of this work and incorporate any appropriate new information or techniques in his work.

Military and NAS review of the contractor's work should be made at quarterly intervals. Upon completion of the criteria, the NAS should be asked to review the protocol and procedures which were followed in their preparation. The criteria should be submitted to the Surgeons General for approval.

The recommended course from the Development Plan to Potable Criteria is illustrated by Figure 6, a Gantt Chart, and Figure 7, a PERT chart.

LEVEL OF EFFORT

The levels of effort required have been estimated for: (1) employing a four man task group of technical specialists to develop the potable water reuse criteria, with secretarial and other staff support services supplied by a consulting firm, and (2) employing a consultant to develop the potable reuse criteria. If consideration is given to preparation of the criteria by contract with the National Academy of Sciences, then a proposal should be obtained directly from them. However, it probably will not differ greatly in magnitude from the other two approaches.

The estimates do not include estimates of work done by the military or the costs incurred by military personnel in attending review meetings. Neither do the estimates include the cost of NAS review.

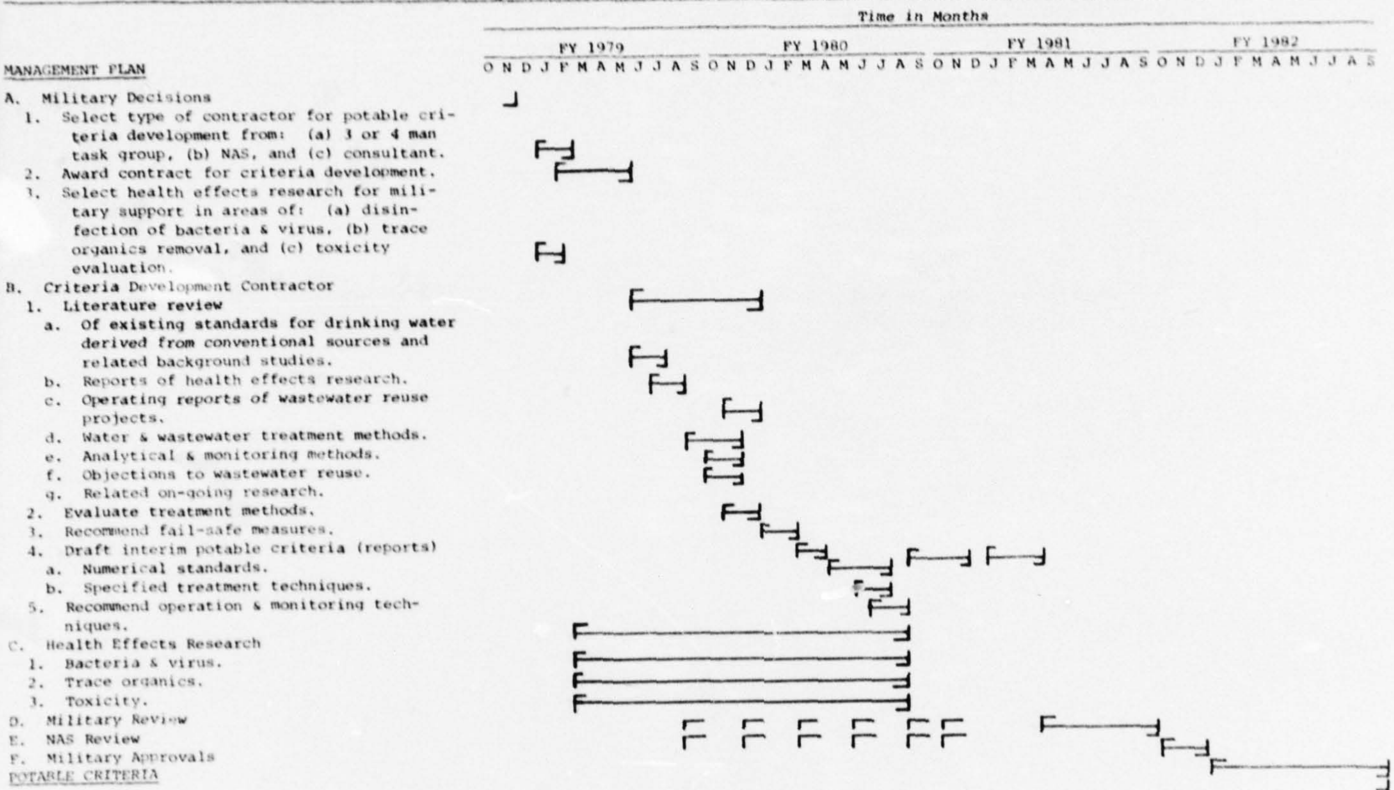
The estimated levels of effort for developing potable water criteria by employing a three man task group are shown in Table 7 and by a consulting firm are given in Table 8.

The question of military support for health effects research is a difficult one to evaluate. It may be possible to gain scientific and health approval based on existing information. However, it is also possible that research completed by the military within the next year or two could be a decisive factor. There is also a third possibility which is that the potable reuse of renovated wastewater will not be approved by 1983 regardless of new research results.

Our best judgment is that it might be appropriate for the military services to support research in: (1) bacteria and virus disinfection, (2) removal of toxic substances and on-line monitoring of toxicity, and (3) removal of trace organics at a total level of effort of about six

FIGURE 6

GANTT CHART FOR DEVELOPMENT OF QUALITY CRITERIA FOR POTABLE WATER DERIVED FROM RENOVATED WASTEWATERS



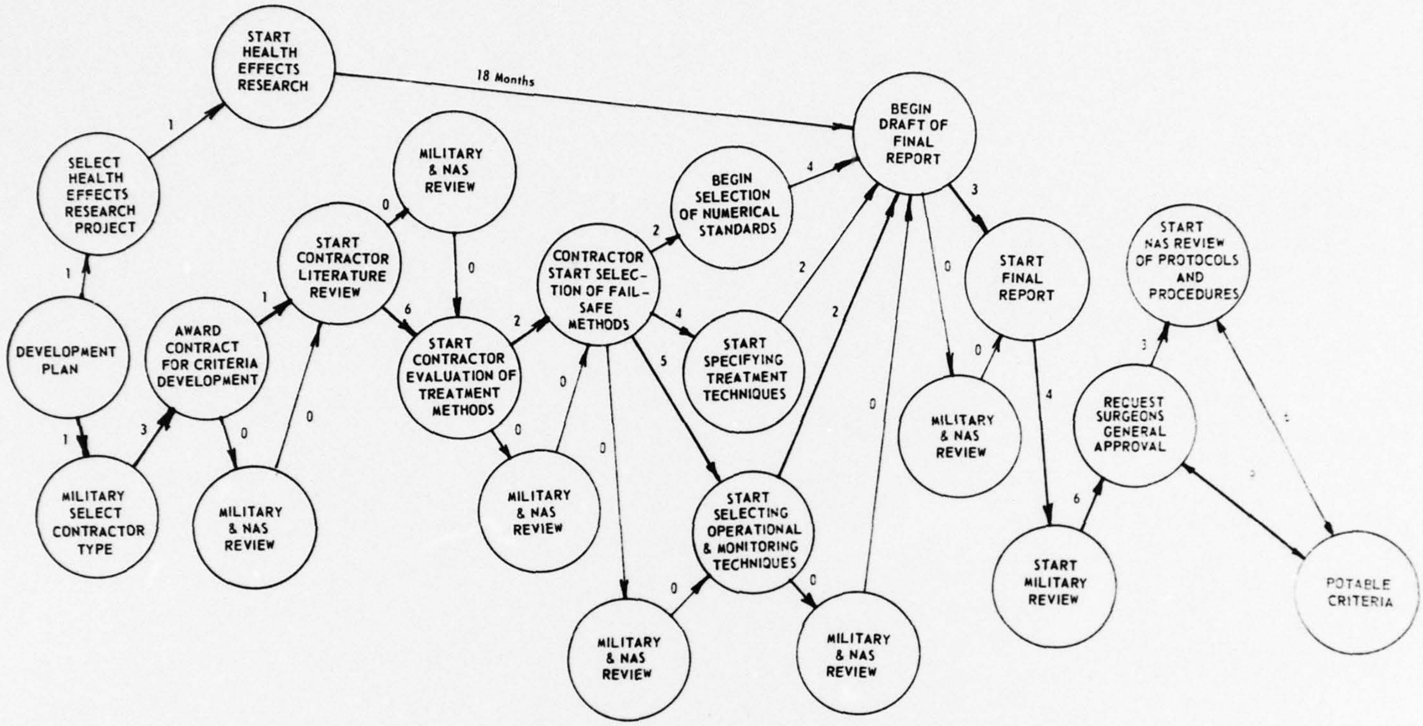


Figure 7. PERT Chart for development of quality criteria for potable water derived from renovated wastewaters.

man-years, or two man-years for each of the three areas of research.

If treatment techniques are specified in lieu of numerical standards, it may be necessary to support demonstration projects to verify or solidify the selection. It is estimated that this might also require two man-years of effort, plus an expenditure of $50,000 to $100,000 for a pilot or demonstration plant.

TABLE 7
ESTIMATED LEVEL OF EFFORT FOR DEVELOPMENT OF POTABLE WATER CRITERIA BY THREE MAN TASK GROUP OF TECHNICAL SPECIALISTS

Professional Labor	36 man-months	
Secretarial Labor	2 man-months	$ 2,000*
Travel		18,000
Per Diem		6,000

TABLE 8
ESTIMATED LEVEL OF EFFORT FOR DEVELOPMENT OF POTABLE WATER CRITERIA BY CONTRACT WITH CONSULTING FIRM

Professional Labor	30 man-months	
Secretarial Labor	1.5 man-months	
Travel		$ 3,500*
Per Diem		1,500

*1978 basis